



8EHQ-0395-13358

AlliedSignal Inc.  
P.O. Box 1057  
Morristown, NJ 07962-1057

ORIGINAL

A

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RETURN RECEIPT REQUESTED

March 1, 1995

U.S. Environmental Protection Agency  
Office of Pollution Prevention and Toxics  
TSCA 8(e) Coordinator  
401 M. Street, SW  
Washington, DC 20460

Contains No CBI

RE: Toxic Substances Control Act - Section 8(e) Substantial Risk Report

Dear Sir:

AlliedSignal operates a facility south of Pittsburgh, KS located on a portion of a 2332 acre industrial tract commonly referred to as the "Jayhawk Site". A report and health risk assessment was commissioned by the Kansas Department of Health and Environment for approximately 750 acres of the Jayhawk Site. AlliedSignal's facility involves approximately 24 acres of the area involved in the study. The study examined potential health risks associated with environmental contaminants at the site originating from operations prior to AlliedSignal's tenure.

A copy of the report has been received by AlliedSignal from the Jayhawk Site Group, a group of companies that have signed an agreement with the Kansas Department of Health and Environment to perform a Remedial Investigation/Feasibility Study and Risk Assessment for the 750 acre portion of the Jayhawk Site. The report indicates a potential lifetime cancer risk for the AlliedSignal property of  $1 \times 10^{-4}$  based upon environmental sampling for several organic and inorganic materials. Accordingly, AlliedSignal is submitting this report to the 8(e) office as Substantial Risk Information. AlliedSignal has not had an opportunity to thoroughly examine the report, its assumptions or its conclusions, but our preliminary examination indicates that there may be problems with the assumptions used in the study leading to an overstated health risk.

Further, EPA should be aware that the report has been previously submitted to the Agency's 8(d) office as a Health and Safety Study due to several reported materials presence on the active 8(d) list. The report was submitted by CH2M Hill, contractor for the Jayhawk Site Group. A copy of the cover letter is attached.

If you have any questions regarding this communication, do not hesitate to contact me at 201-455-2733.

Sincerely,

D. Levine

D. Levine

Director - Product Safety and Integrity



8EHQ-95-13358  
INIT 03/06/95



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8/3/95



Engineers  
Planners  
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(2)

February 22, 1995

RME32921.P3.F1

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RECEIVED

Attention: 8D Health and Safety Reporting Rule

Subject: TSCA-8D Health and Safety Reporting Rule

Please find attached the Final Baseline Risk Assessment for the Jayhawk Plant in Jayhawk, Kansas. The referenced document was received by all parties of the Jayhawk Site Group (Koch Chemicals, Chevron Chemicals, Allico, and UTC) on or about January 25, 1995 from the Kansas Department of Health and Environment. We are submitting the referenced document in accordance with TSCA-8D Health and Safety Reporting Rule. The following compounds are on the TSCA-8D list:

- 67-66-3 Methane, trichloro-
- 75-34-3 Ethane, 1,1-dichloro-
- 86-74-8 9H-Carbazole
- 91-20-3 Naphthalene
- 100-41-4 Benzene, ethyl-
- 107-06-2 Ethane, 1,2-dichloro-
- 108-95-2 Phenol
- 126-99-8 Chloroprene--1,3-Butadiene, 2-chloro-
- 127-18-4 Ethene, tetrachloro-
- 129-00-0 Pyrene
- 7440-48-5 Cobalt

Compounds that have been sunseted prior to 1993, when the risk assessment study was initiated, have not been included.

Environmental Protection Agency  
Page 2  
February 22, 1995  
RME32921.P3.F1

Sincerely,

CH2M HILL



Charlie Krogh  
Project Manager, Jayhawk Site Group

Attachment

all/tsca.let

cc: Beth Kellar/Allied Signal (no attachment)  
Kathy Emerson/Chevron (no attachment)  
Tom Segar/Koch (no attachment)  
Steve Mahaffey/Allco (no attachment)  
David Shear/UTC (no attachment)

BASELINE RISK ASSESSMENT  
FOR THE  
JAYHAWK SITE  
GALENA, KANSAS

VOLUME I

Prepared for:

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT  
Bureau of Environmental Remediation  
Topeka, Kansas 66612

Work Assignment No.	:	0003
Date Prepared	:	January 4, 1995
Contract No.	:	29103
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## EXECUTIVE SUMMARY

PRC Environmental Management, Inc. has prepared this baseline risk assessment report for the Kansas Department of Health and Environment for Work Assignment No. 0003 under Contract No. 29103. The report assesses the potential human health and environmental impacts associated with the Jayhawk Kansas (Jayhawk) site located in Galena, Kansas. The report is prepared in accordance with Environmental Protection Agency (EPA) standard guidance for performing baseline risk assessments and other guidance documents where appropriate.

The Jayhawk site has operated since approximately 1941. The site initially operated as a Department of Defense (DOD) ordnance plant. The plant produced anhydrous ammonia until 1945. Ownership of the plant changed several times from 1945 to 1984. Sale of parts of the facility also occurred during this time. The owners of the site during 1992 included:

- Chevron Chemical Company
- Universal Technical Corporation
- Allco Chemical Company
- Koch Chemical Company

All four of the owners comprise the Jayhawk Site Group. Operations at the site have included the production of:

- Anhydrous ammonia
- Nitric acid
- Liquid ammonium nitrate
- Finished fertilizer grade ammonium nitrate
- Ammoniating solution
- Dry ice
- Methanol
- Carbamate-based pesticide
- Uranium dioxide
- Pyromellitic acid



- 3,4,3',4-Benzophenone tetracarboxylic dianhydride
- Pesticides
- Pharmaceutical intermediates
- Fragrances

In addition, a cooling tower and sanitary and chemical sewer systems were operated on the site. The cooling tower was allegedly the source of chromium contamination that DOD has apparently accepted responsibility for. The sanitary sewer system was used to collect sanitary waste and chemical laboratory waste, discharging them to a septic tank and leach field. The chemical sewer system collected wastes from production operations and discharged to two evaporation ponds that were closed in 1984.

Allco/Weston performed a site assessment in 1991. CH2M Hill performed a remedial investigation, and Allied Signal performed a site assessment in 1992, prior to its acquisition of the Koch portion of the site. Data from these three studies were quantitatively used in the risk assessment. To evaluate current occupational exposures, the Jayhawk site was divided into three areas (A, B, and C) based on these three studies. Area A includes the central portion of the site and was sampled by Allied Signal. Area B includes the southern portion of the site and was sampled during the remedial investigation. Area C includes the northern portion of the site and was sampled by Allco/Weston.

The sampling approach used by both Allco/Weston and Allied Signal did not employ a random sampling design, but used a focused design. In both of these studies, samples were taken at areas anticipated to be contaminated. These data sets are the only data available for these portions of the Jayhawk site. Although there are uncertainties associated with the data as to true representativeness of the contamination at the site, the data sets were deemed acceptable for use in the risk assessment. The data were evaluated according to EPA procedures to identify chemicals of potential concern. No preliminary screening of contaminants based on toxicity was performed. In total, 54 chemicals of potential concern were identified. These chemicals include volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls (PCB), dioxins, and metals. Samples collected from surface water and sediments did not appear to be significantly elevated over background samples. Exposure to chemicals of potential concern was evaluated under two sets of land use conditions:

- (1) current land use conditions, which included exposure to employees and trespassers at the site, and
- (2) future land use conditions in which the site is used for industrial development.

The exposure pathways and contaminants that result in significant human health risks at the site were defined. Both upper bound excess lifetime cancer risks and noncarcinogenic hazard indices were calculated. Contaminants that result in the greatest risk include:

- 1,1-Dichloroethene 75-35-1
- 1,2-Dichloroethane 107-06-2
- Carcinogenic polynuclear aromatic hydrocarbons
- Manganese 7439-96-5
- Methylene chloride 75-09-2
- Nitrates
- PCBs 1336-36-3
- Dioxins
- Trichloroethene 71-55-6
- Vinyl Chloride 75-01-4

Total excess cancer risks and their associated exposure scenarios include:

- Current employees
  - 1E-04 for employees working in Area A
  - 3E-05 for employees working in Area B
  - 4E-05 for employees working in Area C
  - 2E-05 for employees exposed to the subsurface soils
- Future employees
  - 2E-03 for employees exposed to site-wide soils and water from the upper shallow aquifer
  - 4E-04 for employees exposed to site-wide soils and water from the lower shallow aquifer
  - 4E-04 for employees exposed to site-wide soils and water from the deep aquifer
- 1E-05 for trespassers who may wander onto the site

For current employees working in Area A and future employees, the total excess cancer risks are significant. Significant excess cancer risks for the current workers are the result of dermal contact with soils in Area A. For the future workers, the significant excess cancer risks are the result of exposure to the upper shallow aquifer and dermal contact with the soils.

Total hazard indices and their associated exposure scenarios include:

- Current employees
  - 2.6E-02 for employees working in Area A
  - 4.8E-01 for employees working in Area B
  - 2.2E-02 for employees working in Area C
  - 1.5E-02 for employees working in the subsurface
- Future employees
  - 1.5E+01 for employees exposed to site-wide soils and water from the upper shallow aquifer
  - 2.0E+00 for employees exposed to site-wide soils and water from the lower shallow aquifer
  - 1.5E+00 for employees exposed to site-wide soils and water from the deep aquifer
- 5.0E-02 for trespassers who may wander onto the site

Hazard index values that are significant are for future occupational scenarios. Only groundwater ingestion of the upper shallow aquifer had a hazard index greater than 1.0. It should also be noted that exposure to nitrates and manganese when summed across scenarios exceeded 1.0.

Currently, there are no data available indicating that ecological receptors are experiencing adverse effects from on-site contaminants. Ecological risks were qualitatively evaluated based on limited information. Ten probable exposure pathways were identified.

## CHAPTER 1

### INTRODUCTION

PRC Environmental Management, Inc. (PRC), received Work Assignment 0003 from the Kansas Department of Health and Environment (KDHE) under Contract No. 29103. Under this work assignment PRC was tasked with performing a baseline risk assessment of the Jayhawk site near Galena, Kansas. To perform the assessment, PRC conducted various tasks. Those tasks included: (1) reviewing site investigation reports, (2) identifying contamination, (3) assessing exposure pathways and toxicity, (4) characterizing risk, and (5) completing a baseline risk assessment report. The methodology used and the results of the risk assessment are described in this report. This baseline risk assessment is based predominantly on data collected during a site assessment done for Allco Chemical Company (Allco) (Weston 1991), during a remedial investigation (RI) conducted at the site for the Jayhawk Site Group by CH2M Hill (1992), and during a site assessment done by Allied Signal (1992).

#### 1.1 SCOPE OF RISK ASSESSMENT AND REPORT ORGANIZATION

PRC conducted this risk assessment in accordance with risk assessment guidelines established by the U.S. Environmental Protection Agency (EPA). The methodology used consisted of the following elements: (1) identification of chemicals of concern, (2) assessment of exposure (3) evaluation of toxicity, and (4) characterization of risk. The site-specific objectives of this baseline risk assessment were to assess the magnitude and probability of actual or potential harm to public health and the environment by releases of hazardous substances from the Jayhawk site. PRC conducted this baseline assessment under the no action alternative assumptions that no further corrective measures will be performed at this site and that maintenance and repair of existing corrective measures will be performed as needed.

PRC quantitatively assessed the risks to humans who might be exposed to contamination through groundwater ingestion, incidental ingestion of soils, dermal contact with soils, and inhalation of particulates and volatile compounds from groundwater. PRC also qualitatively evaluated the ecological risks at the Jayhawk site.

The following section (Section 1.2) details site background and history summaries. It is followed by the following chapters and appendixes:

- Chapter 2 -- "Identification of Chemicals of Potential Concern." This chapter screens the data acceptable for use in the quantitative risk assessment and identifies chemicals of potential concern.
- Chapter 3 -- "Exposure Assessment." This chapter characterizes the contaminant concentrations, exposure routes, transport pathways, potentially exposed populations, and chemical doses that may result from exposure.
- Chapter 4 -- "Toxicity Assessment." This chapter identifies the types of health effects that may result from human exposure to the chemicals of potential concern and the dose-response values that can be used in combination with exposure levels to predict potential health risks.
- Chapter 5 -- "Risk Characterization." This chapter estimates the risks for the health effects of concern using dose-response data and human exposure information. A discussion of uncertainties is included.
- Chapter 6 -- "Ecological Risk Assessment." This chapter details the qualitative results of the ecological risk assessment.
- Chapter 7.0 -- "Conclusion." This chapter summarizes the main points of the risk assessment.
- Appendix A -- This appendix presents data summary tables that provide information on types of analytes and contaminant concentrations.
- Appendix B -- This appendix provides the methodology used to estimate exposure during showering.
- Appendix C -- This appendix provides the methodology used to estimate exposure to soil particulates.
- Appendix D -- This appendix provides all of the risk calculations.

## **1.2 BACKGROUND**

The following site background information was derived from the RI performed by CH2M Hill (1992) for the Jayhawk Site Group (JSG) unless noted in the text. The JSG consists of the Chevron Chemical Company (Chevron), the Koch Chemical Company (Koch), the Allco, and the Universal Technical Corporation (UTC), all owners of the site at the time of the RI.

### 1.2.1 Site Description

The Jayhawk site is situated in a rural area of southeastern Cherokee County, about 2.5 miles northwest of Galena, Kansas. The entire property encompasses 2,332 acres, of which about 750 acres are used for industrial purposes and is the area that is defined as the Jayhawk site (Figures 1-1 and 1-2). The other 1,574 acres are used for agricultural purposes by local residents. The Spring River borders the Jayhawk area to the east and south, and Shawnee Creek is to the west of the area. Primarily rural, residential property lies to the north (Figure 1-1).

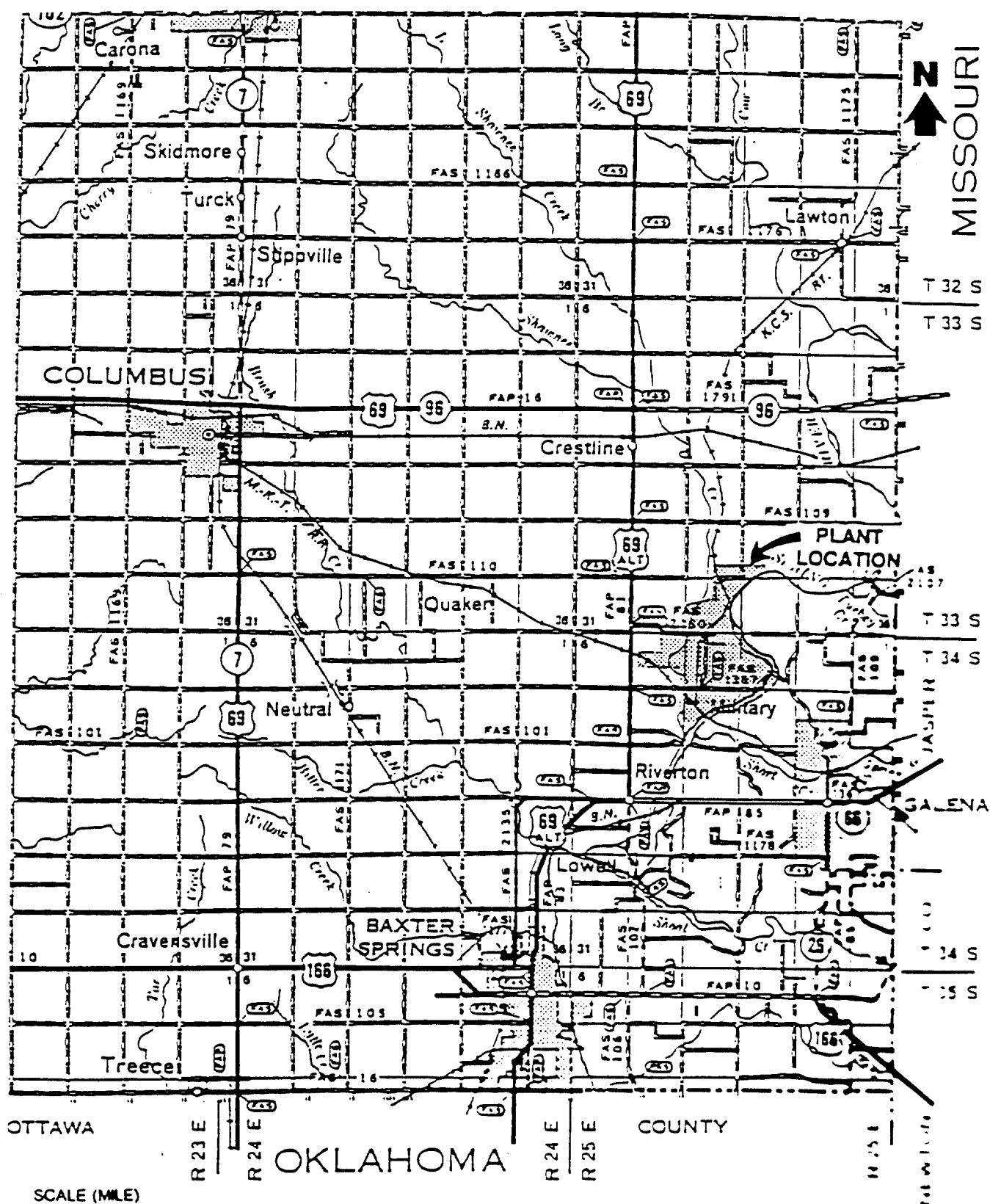
The site lies within Section 33, Township 33 South, Range 25 East, and Sections 3, 4, and 9, Township 34 South, Range 25 East. It also includes an area described as the North one-half of Section 5, Township 34 South, Range 25 East.

The topography of the site consists of generally low relief areas except for the lowlands developed by the erosional character of both the nearby Shawnee Creek and the Spring River, both of which flow to the south (Weston 1991) (Figure 1-1).

The region around the site has a long history of mining and mining-related activities. This area is located in the Tri-state Mining District, one of the richest lead and zinc ore deposits in the world, covering about 500 square miles in Oklahoma, Kansas, and Missouri. The EPA has performed numerous studies for the Galena Superfund subsite, also located in Cherokee County approximately 2 miles southeast of the Jayhawk site. The RI stated that the results of EPA's investigation of the Galena Superfund site shows that mining activities in the area have affected the shallow groundwater aquifer, surface water, and soils. Constituents of concern include heavy metals. It is possible that the Jayhawk site has been affected by natural mineralization and mining-related activities, including the operation of the Galena primary lead smelter located approximately 2 miles southeast of the Jayhawk site.

### 1.2.2 Site History

The Jayhawk site has had several owners and operators during the past 50 years. The following paragraphs summarize the ownership, operational, and waste management activities at the site.



SCALE (MILE)



CHEROKEE COUNTY

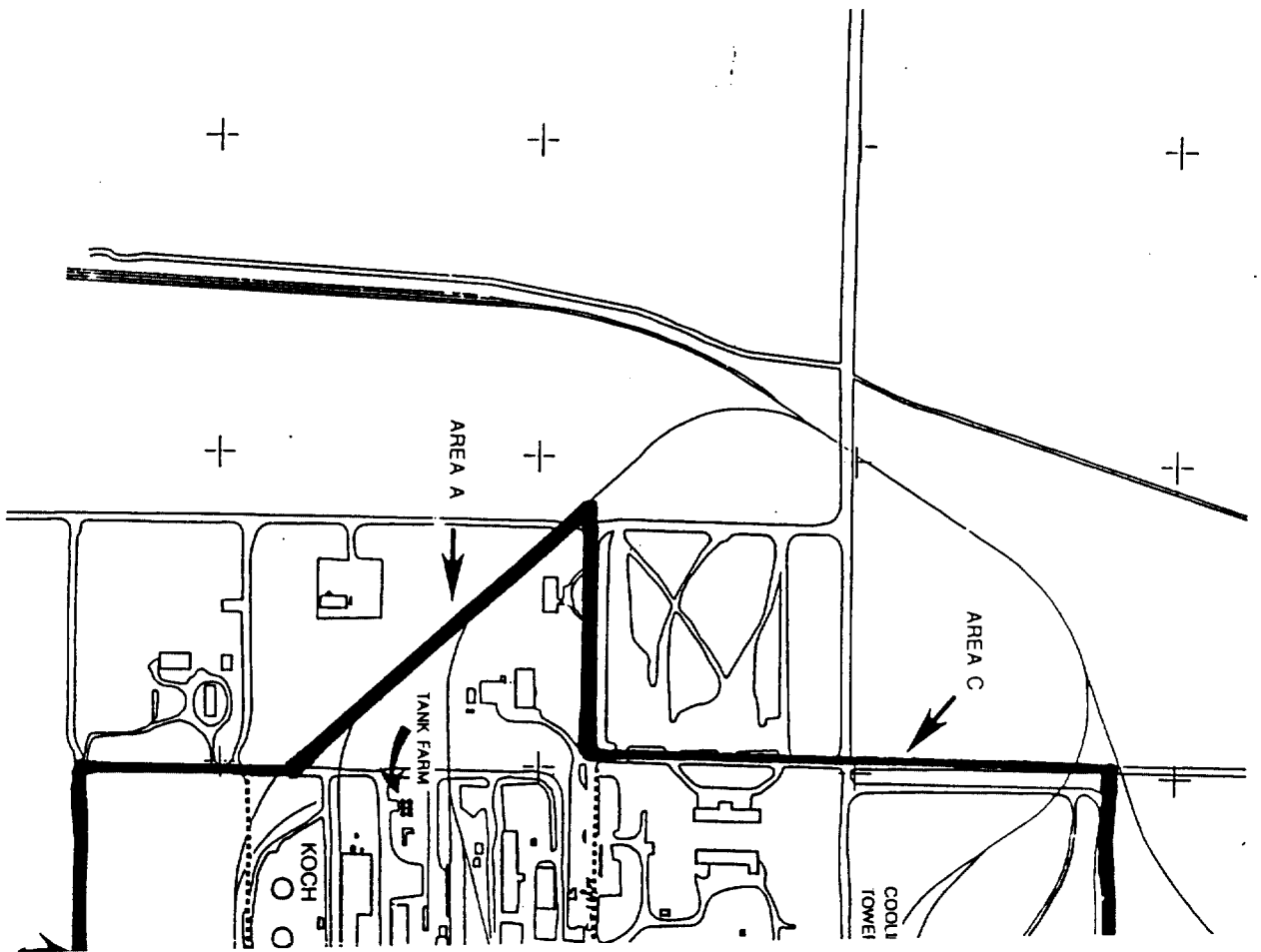


KANSAS

JAYHAWK SITE  
GALENA, KANSAS

FIGURE 1-1  
SITE LOCATION

**PRC** ENVIRONMENTAL MANAGEMENT INC.



SCALE (FEET)





The first industrial use of the site began in 1941 when the Department of Defense (DOD) established an ordnance plant there that was operated by the Military Chemical Works of Kansas City, Missouri. This plant produced liquid anhydrous ammonia from 1941 to 1945. The plant employed 795 people and produced a total of 295,000 tons of ammonia and 152,000 tons of ammonium nitrate. Five of the original seven administrative buildings owned by DOD have been destroyed, along with the synthesis departments, the ammonium nitrate plant, cooling tower "C," and an unknown number of storage buildings. Cooling tower "C" was allegedly the source of chromium released to soils. DOD has accepted responsibility for the remediation of this contamination.

In 1948, the War Assets Administration conveyed the facility to Spencer Chemical Company (Spencer). Spencer operated at the site from 1948 until the company was sold to Gulf Oil Chemical Company (GOCC) in 1963. Spencer manufactured the following products at the site:

- Anhydrous ammonia
- Nitric acid
- Liquid ammonium nitrate
- Finished fertilizer grade ammonium nitrate
- Ammoniating solutions (Spensol)
- Dry ice
- Methanol
- Carbamate-based pesticide (Carbyne)
- Uranium dioxide

PRC assumes GOCC continued Spencer's manufacturing operations at the site after buying the company in 1963. GOCC closed the ammonia and gas reforming plants in 1969, and the methanol production facilities in 1970. GOCC operated a nitric acid plant at the site for 6 months in 1970. In 1975, GOCC began producing 3,4,3',4'-benzophenone tetracarboxylic dianhydride (BTDA), an epoxy additive and semiconductor coating. In 1976, GOCC began producing pesticides (herbicides and rodenticide). GOCC produced several other chemicals at the site until 1983, when it terminated its production activities. GOCC sold 52 acres of the plant to Allco in 1983. In 1984, GOCC merged into Chevron, which then sold 938 acres to Thermex Energy Corporation (Thermex).

Throughout its operation at the site, GOCC used the wastewater collection systems existing at the plant when the plant was obtained from Spencer. These systems included a sanitary sewer system and a chemical sewer system.

The sanitary sewer system collected sanitary wastes from buildings throughout the plant discharging them to septic tanks and ultimately leach fields. Historical information indicates that chemical wastes from laboratories at the plant also were disposed of in the sanitary sewers. Records detailing the types and volumes of laboratory wastes disposed of do not exist.

The chemical sewer system received discharges from the specialty chemicals and crop protection operations and from spills. This sewer discharged to two evaporation ponds south of the plant. Each was about 35 acres in size and was designed to be nondischarging. Under abnormally high water conditions, the evaporation ponds overflowed to the 120-acre oxbow lake to the east. Storm sewers at the plant also discharged to the oxbow lake. The evaporation ponds were closed by GOCC in 1984, with KDHE approval.

GOCC stored gasoline and diesel fuel in underground storage tanks (UST) located near the firehouse by the BTDA building. These appear to have been the only USTs located at the facility, and they were removed by Allco in 1985. GOCC stored toluene in aboveground storage tanks at the plant. GOCC installed containment dikes around these aboveground tanks in 1976. There was an airplane landing strip in operation when Spencer and GOCC operated the plant, but it did not include refueling or maintenance operations.

A number of spills occurred during GOCC operations. The largest one occurred in about 1976 when Carbyne was released to the 120-acre oxbow lake, resulting in a fish kill. Another spill occurred in 1970 or 1971, when sodium dichromate reportedly was released from the cooling tower located west of the BTDA building and migrated to the Spring River. This spill also resulted in a fish kill. PRC was unable to determine how many other spills may have occurred at the site.

GOCC also disposed of small quantities of chemical wastes by burning them in an open pit. Carbyne and Barban wastes were also disposed of in this pit. GOCC buried 12,000 empty 5-gallon Carbyne containers in the company landfill with KDHE approval. KDHE instructed GOCC to drain and rinse

the cans prior to disposal and to treat the wastewater prior to discharge to the plant wastewater system.

When Thermex purchased the 938 acres of the site from Chevron in 1984, it began operating a small commercial explosives research facility. Materials produced at its Jayhawk operation were transported to an off-site facility for testing. Thermex sold four of its acres to UTC in 1990. On March 6, 1992, Chevron foreclosed on Thermex and became the owner again of all the property it had sold to Thermex except for the four acres owned by UTC.

UTC was formed in 1990 when it purchased 4 acres of the site from Thermex. UTC currently operates an analytical laboratory.

Allco began operations at the site in 1983, when it purchased the 52 acres from GOCC. Allco purchased an additional 196 acres from Chevron in 1990. Allco has sold approximately half of its property to Koch. Allco currently produces BTDA and pyromellitic acid (PMA) at the site. The production of BTDA generates a nitric acid waste stream, which is neutralized with ammonium hydroxide. Nonhazardous storm water is discharged to the 120-acre oxbow lake.

Koch purchased 25 acres of the site from Allco in 1985 and about 100 additional acres in 1990. Koch produced fragrances and phenyl xylol ethane (PXE). In 1987, Koch replaced the GOCC chemical sewer lines with aboveground piping. Koch abandoned all old manholes and floor drains by filling or plugging them with concrete. Koch also discharges nonhazardous storm water to the 120-acre oxbow lake. In 1993, Koch sold its portion of the facility to Allied Signal.

### 1.2.3 Site Contamination

Groundwater contamination was first discovered at the site in August 1985 when 1,2-dichloroethane was detected above its Kansas action level (KAL) in a well at the site. KDHE instructed Allco, owner of the well and surrounding property, to discontinue using groundwater from this well for potable purposes. Subsequent investigations by Allco and KDHE determined that shallow groundwater at the site contained detectable levels of organic compounds. In addition, nitrate levels greater than nitrate's KAL were reported for both surface water and groundwater. Inorganic

parameters also were detected in groundwater, soils, and surface water. Several volatile and semivolatile contaminants have also been detected at the site. A preliminary assessment (PA) was prepared by KDHE to determine whether the Jayhawk Site qualifies for listing on the National Priorities List (NPL). To date, however, this site has not been listed on the NPL.

JSG signed a consent agreement with KDHE on June 15, 1992. The RI was performed as part of the consent agreement.

## **CHAPTER 2**

### **IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN**

The overall objective of this chapter is to determine the potential contaminants that may have been released or are being released from the Jayhawk site that could potentially cause risk to human health and the environment. PRC met this objective by performing a variety of tasks. First PRC reviewed available data relevant to the site and any recent studies on the nature and extent of contamination. PRC focused its review on the quality of the data and on whether the data would meet the quality criteria established by EPA (1990a). It is critical to the risk assessment that only data that has met rigorous quality assurance/quality control (QA/QC) requirements be used. Once these activities were completed, then PRC identified the potential contaminants of concern. This chapter is organized into five sections:

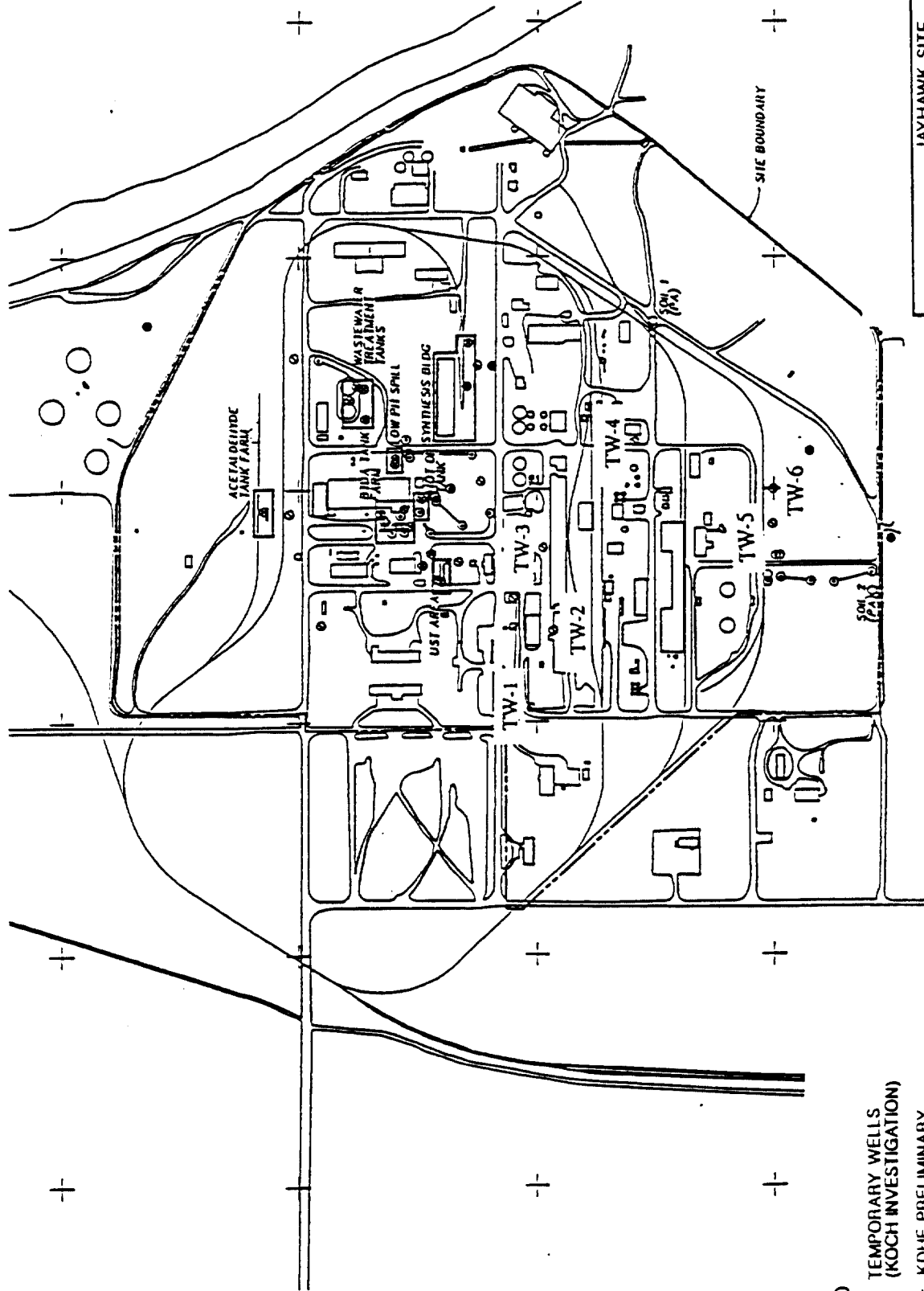
- Section 2.1 -- Limited Studies
- Section 2.2 -- Studies Used for Risk Assessment
- Section 2.3 -- Background Sampling
- Section 2.4 -- Data Evaluation
- Section 2.5 -- Chemicals of Potential Concern

#### **2.1 LIMITED STUDIES**

Overall six investigations have been conducted at the Jayhawk site. These investigations include three that are referenced in this risk assessment only for their historical context and to identify data trends. Based on discussions with KDHE and the JSG, it was decided that data from these three studies would not be used for the risk assessment because of the limited extent of the sampling conducted during these studies and the higher level of QA/QC performed during the other studies. These three investigations are summarized below.

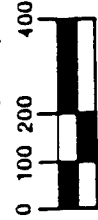
##### **2.1.1 Koch Groundwater Investigation**

In July 1991, Koch installed six temporary monitoring wells. Figure 2-1 shows the well locations. One soil sample was taken during the installation of one well, from 8.0 to 11.5 feet. Cyanide was



- LEGEND**
- TW = TEMPORARY WELLS (KOCH INVESTIGATION)
  - SOIL # = KOHE PRELIMINARY ASSESSMENT
  - ⊗ = ALLCO SAMPLING

SCALE (FEET)



JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-1

PRE-RI SAMPLING LOCATIONS

**PRC** ENVIRONMENTAL MANAGEMENT, INC.

SOURCE: MODIFIED FROM CH2M HILL 1992

detected in the soil sample at 0.43 milligrams per kilogram (mg/kg), and barium (40 mg/kg), chromium (10 mg/kg), arsenic (2 mg/kg), and lead (7 mg/kg) were also detected. Xylene and ethylbenzene were detected at 40 mg/kg and 0.013 mg/kg, respectively. Groundwater sample results showed slightly elevated concentrations of cyanide, mercury, barium, and selenium, when compared to background samples taken during this study, but each was below the KAL. Cadmium was detected in well TW-6 at a concentration greatly exceeding the KAL. Xylene was detected in well TW-5 at a level exceeding the KAL, and tetrachloroethene was detected in TW-1 and TW-2 at levels exceeding the KAL.

### **2.1.2 KDHE Preliminary Assessment**

In April 1990, KDHE collected groundwater, soil, and surface water samples at the Jayhawk site as part of its 1990 PA. All samples were analyzed for priority pollutant volatile organic compounds (VOC) (the surface water samples were not analyzed for VOCs), pesticides, PCBs, semivolatile compounds, heavy metals, and other inorganic constituents.

Lead was detected in a soil sample at 853 mg/kg. Several semivolatile compounds and PCBs (Aroclor 1254) also were detected in soil samples (KDHE 1990). Semivolatile compounds were detected in soil at levels less than 10 mg/kg. PCBs were detected at 44 mg/kg. Groundwater samples were collected from two monitoring wells and the on-site production well. Results showed xylene, chloroform, and trichloroethene (TCE) contamination in the Warsaw and Burlington Keokuk aquifers, and 1,2-dichloroethane (1,2-DCA) contamination in the production well. Five surface water samples were collected from Spring River during the PA. The only organic compound detected was bis(2-ethylhexyl) phthalate detected once at 15.6 micrograms per liter ( $\mu\text{g/L}$ ). Both upstream and downstream samples contained elevated concentrations of metals.

### **2.1.3 KDHE Site Screening Investigation**

KDHE conducted additional groundwater sampling in July 1991 as part of a site screening investigation (SSI). Low levels of xylene, benzene, TCE, and 1,2-DCA were detected. Cadmium, chromium, and lead also were detected at levels exceeding their KALs. The results obtained during the SSI confirmed previous sampling results (CH2M Hill 1992).

## 2.2

## STUDIES USED FOR RISK ASSESSMENT

As discussed earlier, three studies at the Jayhawk site provide the data that was used in the risk assessment. The three studies were performed by three different entities. The first was a property transfer assessment conducted by Allco, the second was the RI conducted by the JSG, and the third was the environmental assessment conducted for Allied Signal. Appendix A contains the sample results used in the risk assessment from each of the studies. A summary of the studies and their results are presented below.

### 2.2.1 Allco Environmental Assessment

In 1989 and 1990, Allco conducted a property transfer environmental assessment to investigate potentially contaminated source areas at the Jayhawk site. As part of the assessment, both soils and groundwater were sampled. The following areas were investigated in a surface soil investigation (Weston 1991): the BTDA tank farm, the hot oil tank area, the wastewater treatment tanks, the acetaldehyde tank farm, the low pH spill area, the UST area, and the synthesis building. Below is a summary of what was found at each of these areas (see Figure 2-1 for locations).

- **BTDA Tank Farm** – At the BTDA tank farm, xylene was detected in four of the five surface soil samples taken. The concentrations ranged from 0.02 to 2,400 mg/kg. Methylene chloride was detected at 530 mg/kg in one surface soil sample. This level exceeds the proposed KAL. Phenanthrene was detected in one surface soil sample at 8.7 mg/kg. Three of these samples also were analyzed for metals. Chromium, copper, mercury, lead, and zinc were detected in all three of the samples. Cadmium and vanadium were detected in two of the three samples that were analyzed. In addition, numerous soil boring samples were taken. Xylene was detected in the soil borings at levels ranging from 0.02 mg/kg to 7,400 mg/kg.
- **Hot Oil Tank Area** – A surface soil sample and soil boring samples were collected near the hot oil tank located south of the BTDA building. Petroleum hydrocarbons were detected in the soil boring at levels as high as 1,110 mg/kg. Aroclor 1254 was detected at a concentration less than 1 mg/kg. Xylene was detected in the 0- to 2-foot-interval at 0.5 mg/kg. Acetone and methylene chloride were detected at 0.06 mg/kg and 0.021 mg/kg, respectively, in the 8- to 10-foot interval.
- **Wastewater Treatment Tanks** – Three soil borings and one surface soil sample were taken in this area. Total petroleum hydrocarbons were detected at 294 mg/kg in the surface soil sample. Nitrate/nitrite was detected at 29.3 mg/kg in the 4.5- to 6.5-foot interval of the boring.



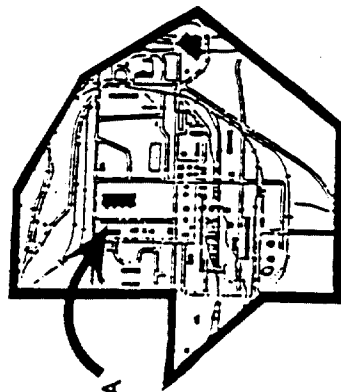
- **Acetaldehyde Tank Farm** – Three samples from one soil boring and one surface soil sample were taken in this area. Nitrate/nitrite was detected at 1.5 mg/kg in the surface sample but was not detected in the three subsurface samples from the same boring. Acetaldehyde was below the detection limit (10 mg/kg) in all samples, and no other parameters were detected.
- **Low pH Spill Area** – Two soil borings were drilled to a depth of 13 feet and sampled in the area where a low-pH spill had occurred. Xylene was detected in all samples ranging from 3 mg/kg to 26,000 mg/kg. Xylene was detected in the samples collected from 11 to 13 feet below the ground surface at 18,000 and 1,000 mg/kg. Ethylbenzene also was detected at 33 and 32 mg/kg as was methylene chloride (8.8 mg/kg) and acetone (9.7 mg/kg) at low levels.
- **UST Area** – In the former UST area, three borings were sampled. Lead was detected in the samples ranging from 10.1 to 171 mg/kg at SB15 from the 0- to 2-foot interval. Lead analyses from two of the samples exceeded the proposed KALs for lead in soils. Low levels of benzene, toluene, ethylbenzene, and xylene were detected in some of the samples. All detections of these compounds, though, had concentrations less than 1 mg/kg.
- **Synthesis building** – Three soil borings were sampled near the synthesis building. One sample showed petroleum hydrocarbon levels at 1,990 mg/kg and PCB (Aroclor 1254) levels of 0.1 mg/kg in the 1- to 3-foot interval. No other compounds were detected.

The groundwater sampling done for this investigation was conducted in the upper shallow zones. The results indicated the presence of xylene in the vicinity of the BTDA building. Several chlorinated compounds were also detected in groundwater. The compounds detected included (1) chloroform with concentrations up to 130 microgram per liter ( $\mu\text{g/L}$ ), (2) carbon tetrachloride with concentrations up to 110  $\mu\text{g/L}$ , (3) 1,1,1-trichloroethane with concentrations of 5  $\mu\text{g/L}$  or less, (4) TCE with concentrations up to 130  $\mu\text{g/L}$ , and (5) tetrachloroethene with concentrations up to 170  $\mu\text{g/L}$ . KALs in groundwater were exceeded for TCE in monitoring well (MW)-7D (shown on Figure 2-2), for tetrachloroethene in MW-1D and MW-4D, for carbon tetrachloride in MW-1D, for benzene in MW-3D, and for xylenes in MW-3D and in five of the eight recovery wells (Figure 2-2). The detection of methylene chloride and acetone appears to be an artifact of the analytical process used by the laboratory (Weston 1991).

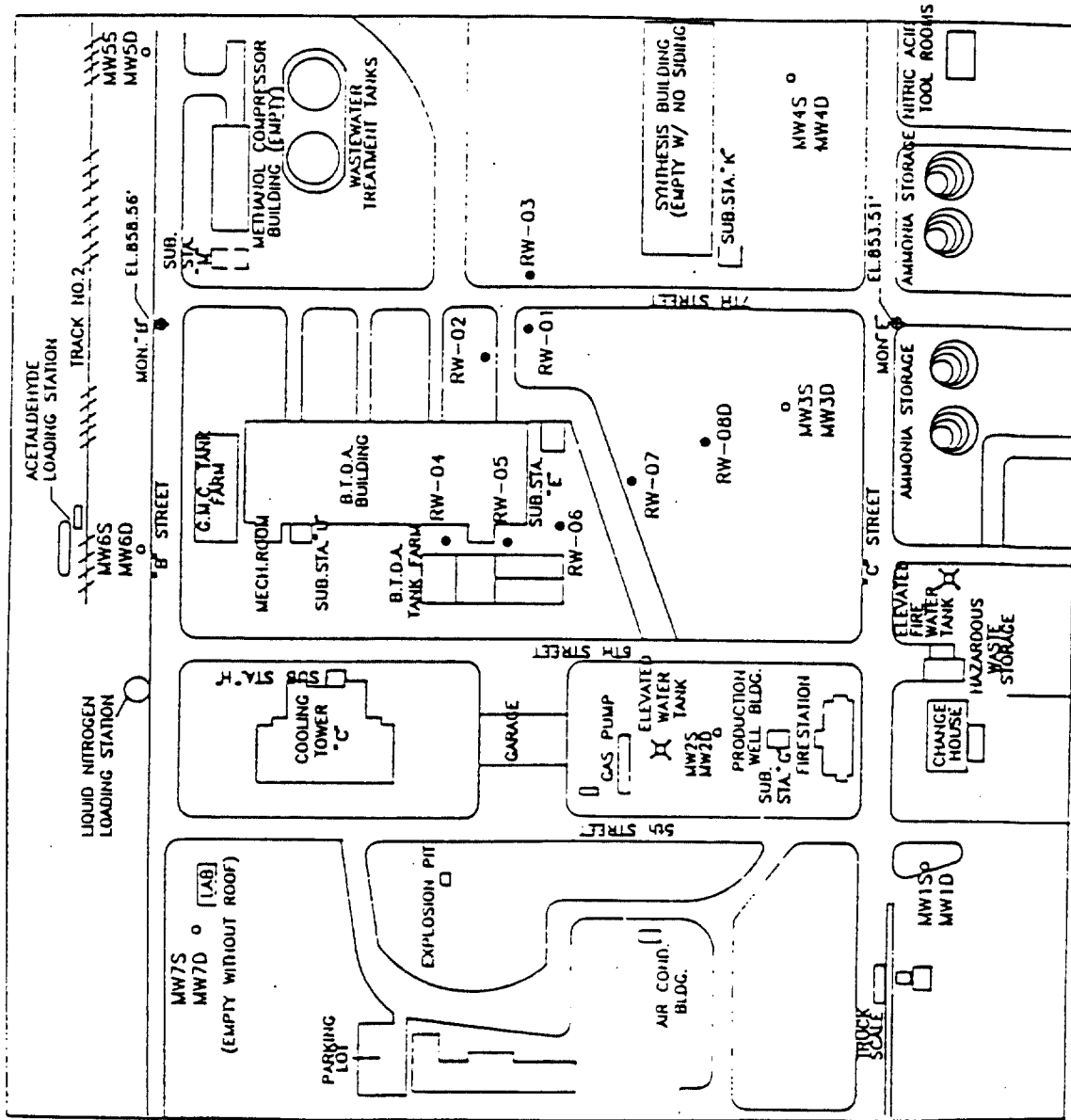
Several metals were detected in the groundwater samples. However, only one metal, cadmium, was detected at levels above the KAL; this occurred in only monitoring two wells.



JAYHAWK SITE



ALCO AREA



LEGEND

- RW-01 RECOVERY WELL
- MW45 MONITOR
- MW40 WELL NEST

NOT TO SCALE

SOURCE: MODIFIED FROM WESTON 1992

JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-2  
ALCO GROUNDWATER WELL  
LOCATIONS

**PRC** ENVIRONMENTAL MANAGEMENT, INC.

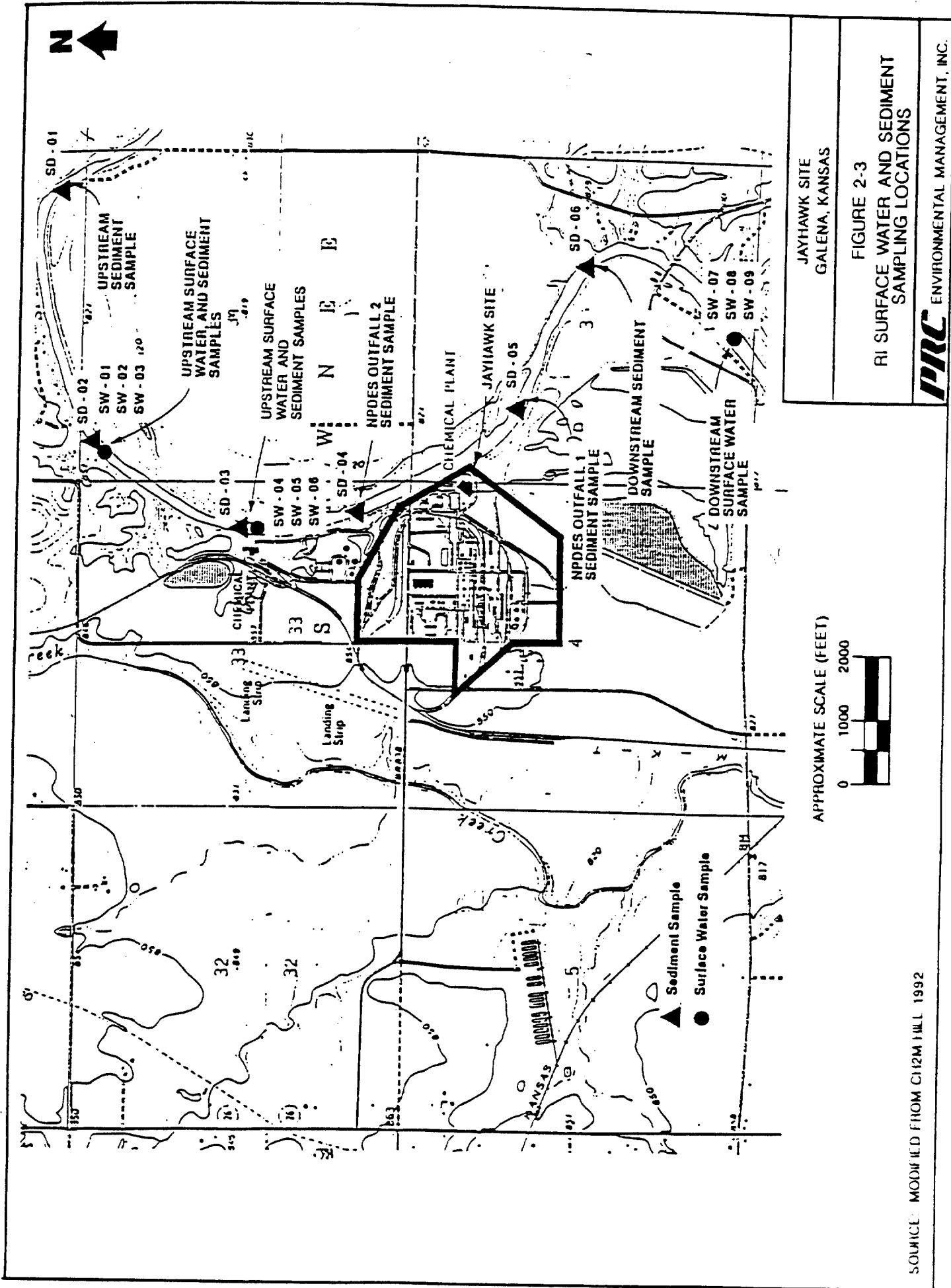
Time-series sampling was performed on the Jayhawk production well (Figure 2-2). The production well was shut down for 48 hours prior to sampling to allow static conditions to be established. Samples were then collected at 0, 5, 15, 45, 90, 180, 360, 720, and 1,440 minutes. The time-series sampling results detected 1,2-DCA at levels ranging from 24 to 62  $\mu\text{g/L}$ . The 1,2-DCA reached a maximum value of 62  $\mu\text{g/L}$  after 5 minutes of pumping and decreased continually to 24  $\mu\text{g/L}$  after 360 minutes. Between 360 minute and 1,440 minutes the level of 1,2-DCA increased slightly to 36  $\mu\text{g/L}$ . All of these detections exceeded the KAL for 1,2-DCA, which is 5  $\mu\text{g/L}$ . No other VOCs were detected.

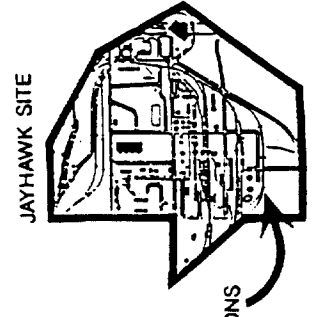
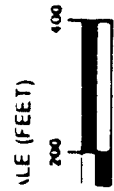
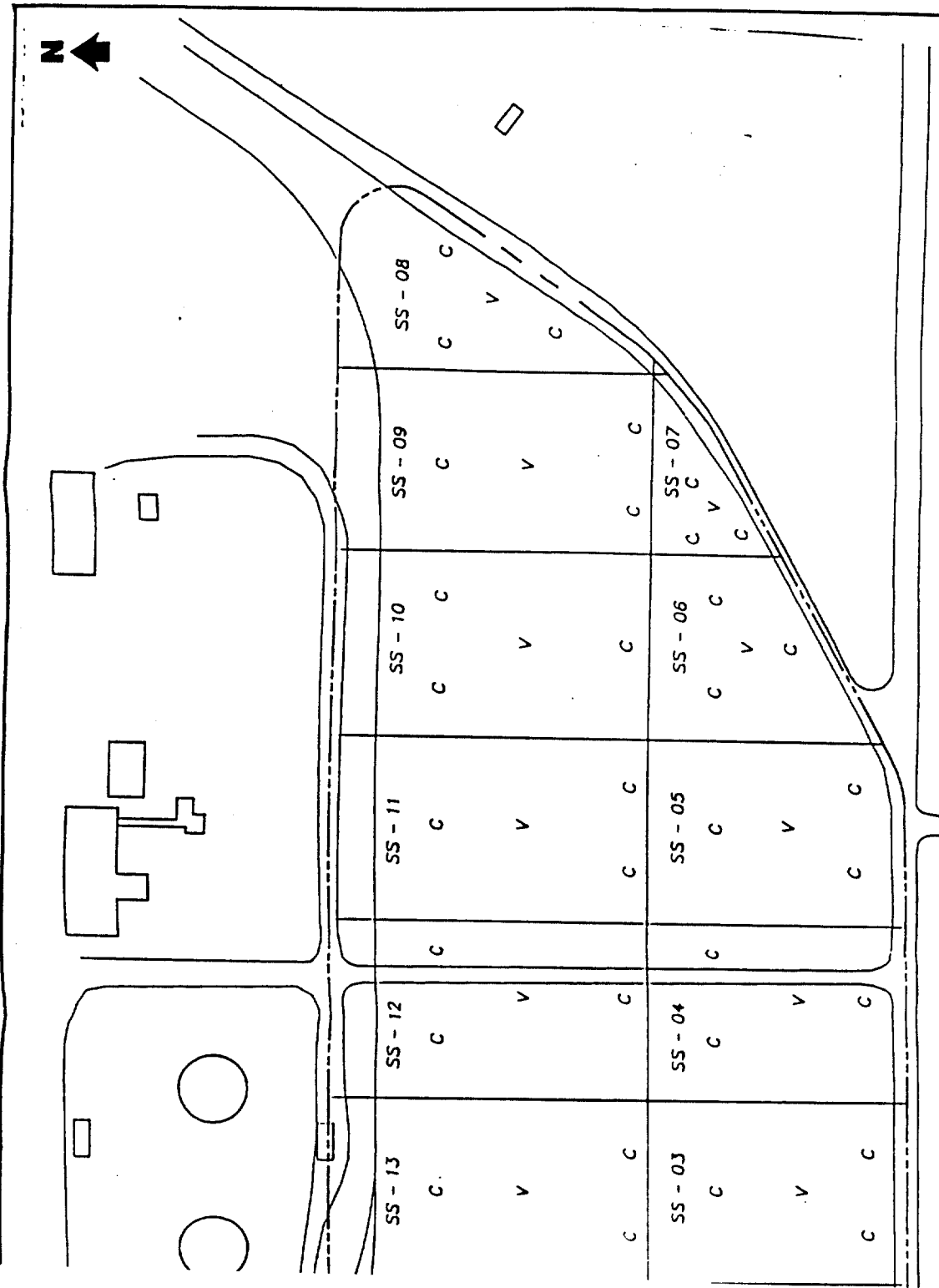
### 2.2.2 Remedial Investigation Sampling

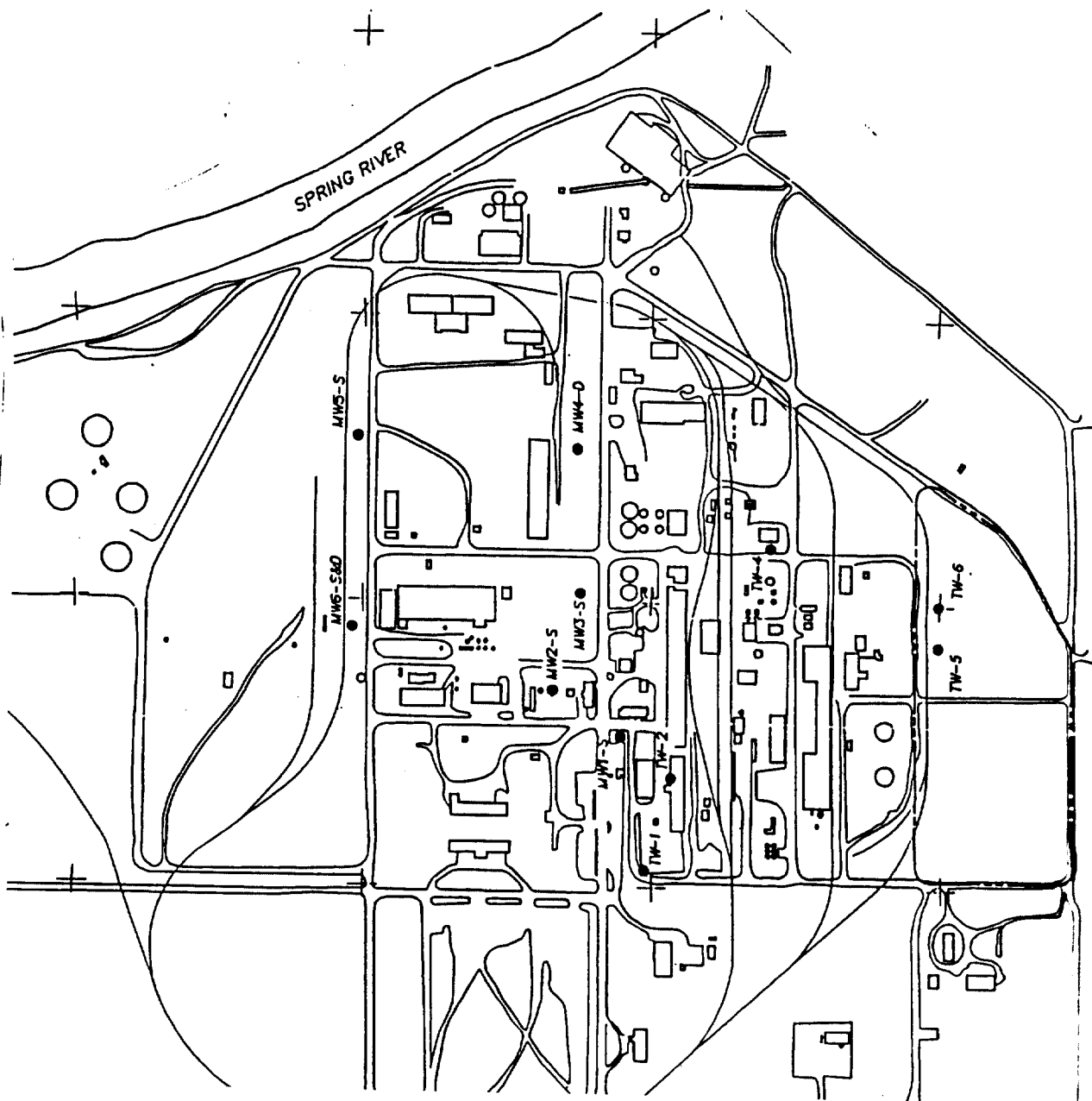
CH2M Hill performed sampling between June 15 and September 24, 1992, as part of the RI. These sampling activities included the following:

- Surface water sampling at the locations shown on Figure 2-3
- Sediment sampling at the locations shown on Figure 2-3
- Soil sampling at the locations shown on Figure 2-4
- Groundwater sampling at the locations shown on Figure 2-5
- Background sampling at the locations shown on Figures 2-6 and 2-7

During the RI, surface water samples were collected at three locations on the Spring River. Two samples were located upstream and one downstream of Jayhawk (Figure 2-3). Samples were analyzed for VOCs, metals, nitrate, total hardness, and sulfate. Also, six sediment samples were collected in the Spring River near the site. Three of the samples were located upstream, two samples were collected from Jayhawk's National Pollution Discharge Elimination System (NPDES) outfalls, and one sample was collected from downstream. Sediment samples were analyzed for VOCs, semivolatiles, metals, and nitrates. The results of surface water and sediment sampling did not show significant increases in contaminant levels at or downstream of this site. Soil sampling was conducted in the southern portion of the Jayhawk site. Groundwater sampling was conducted in both the upper and lower shallow zones during the RI from July 7 through July 10, 1992. Twelve existing wells were sampled (Figure 2-5). A subset of the existing groundwater monitoring wells and the Jayhawk



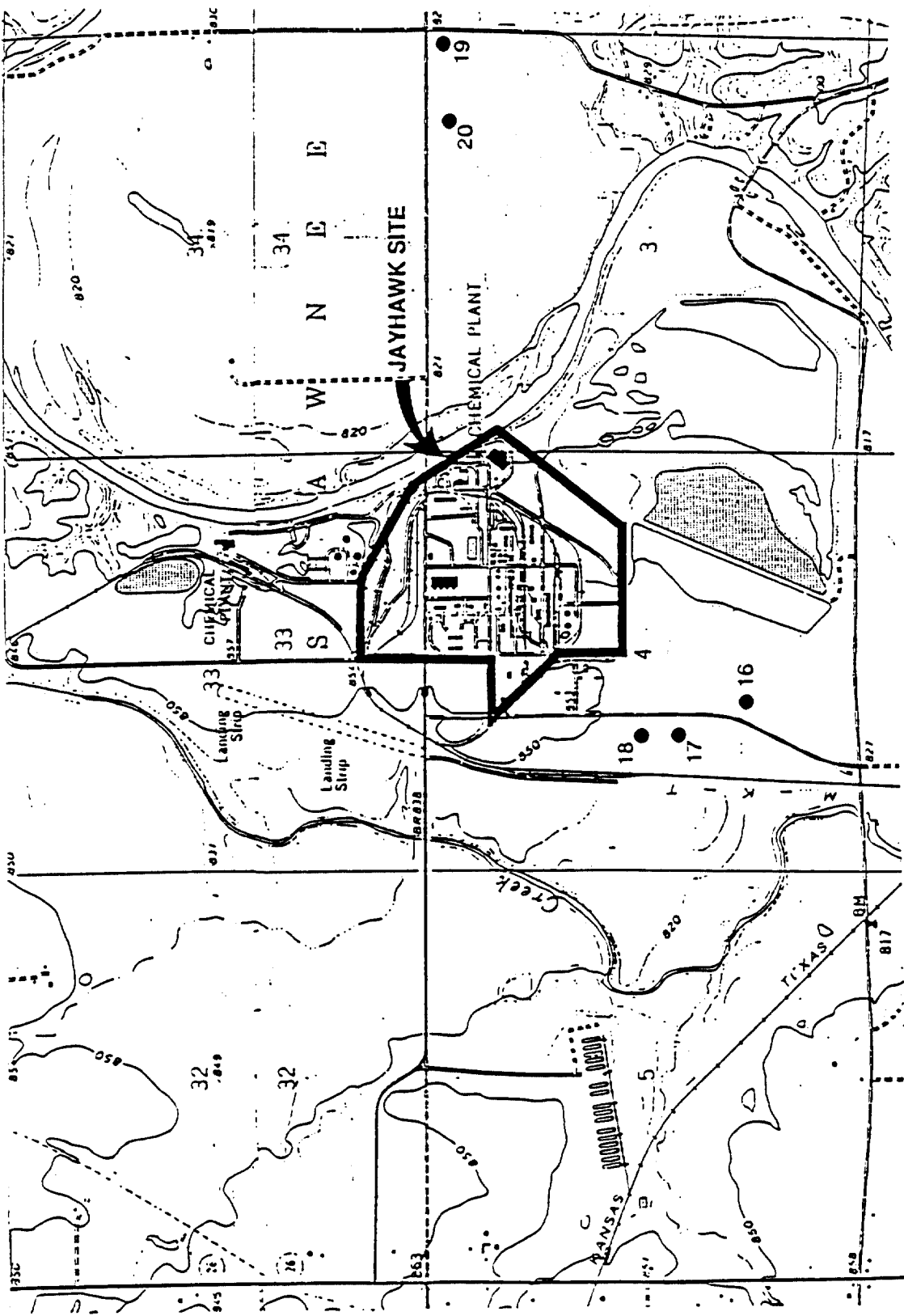




JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-5  
GROUNDWATER MONITORING WELLS

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LEGEND

- BACKGROUND SOIL SAMPLE LOCATION

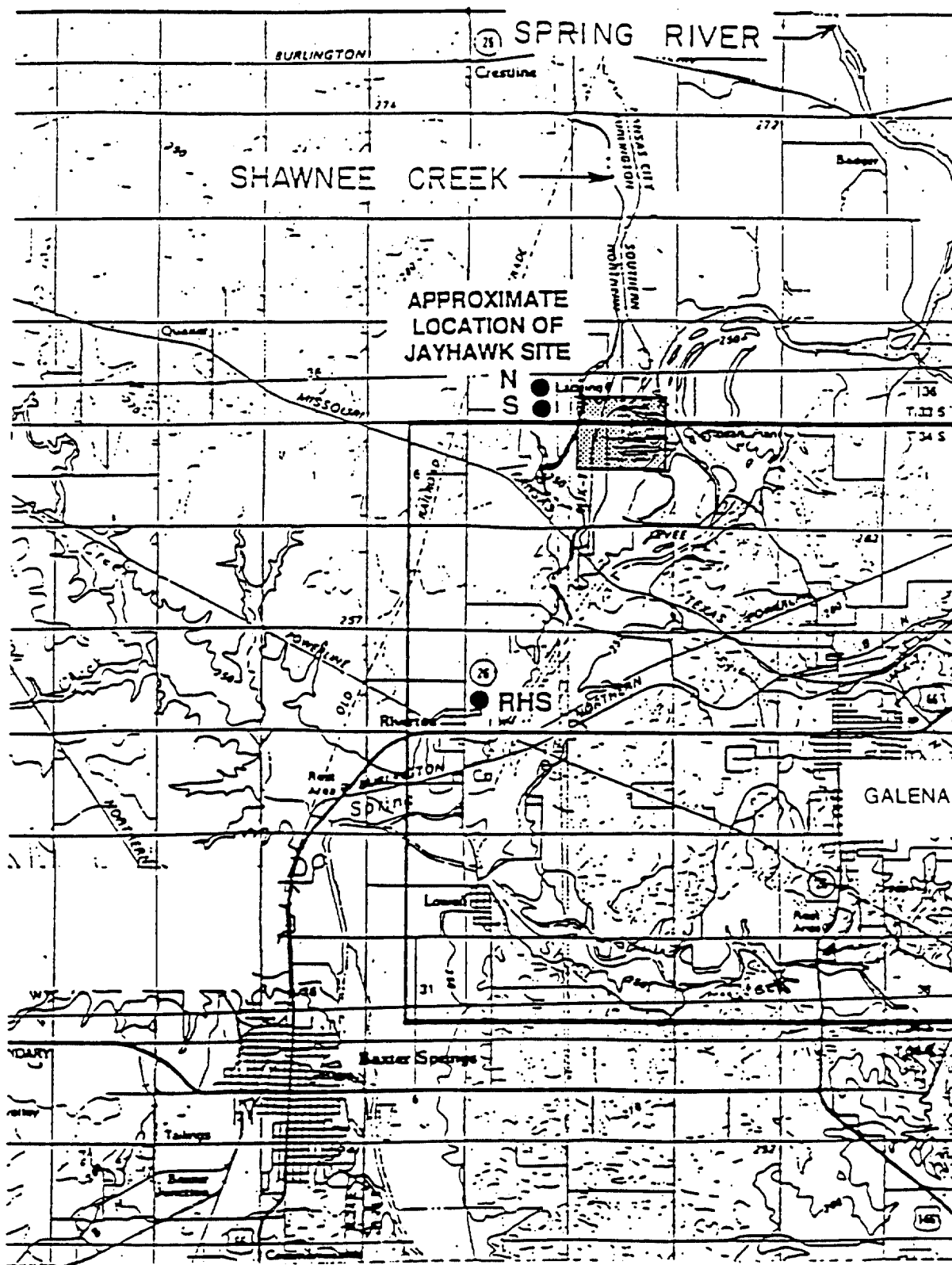
JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-6

BACKGROUND SOIL SAMPLE LOCATIONS



SOURCE: MODIFIED FROM CH2M HILL 1992



# LEGEND

N = NORTH WELL

S = SOUTH WELL

RHS = RIVERTON HIGH SCHOOL WELL

## SCALE (FEET)

0 4000 8000



JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-7  
BACKGROUND WELL LOCATIONS

SOURCE: MODIFIED FROM CH2M HILL 1992

**PRC** ENVIRONMENTAL MANAGEMENT, INC.

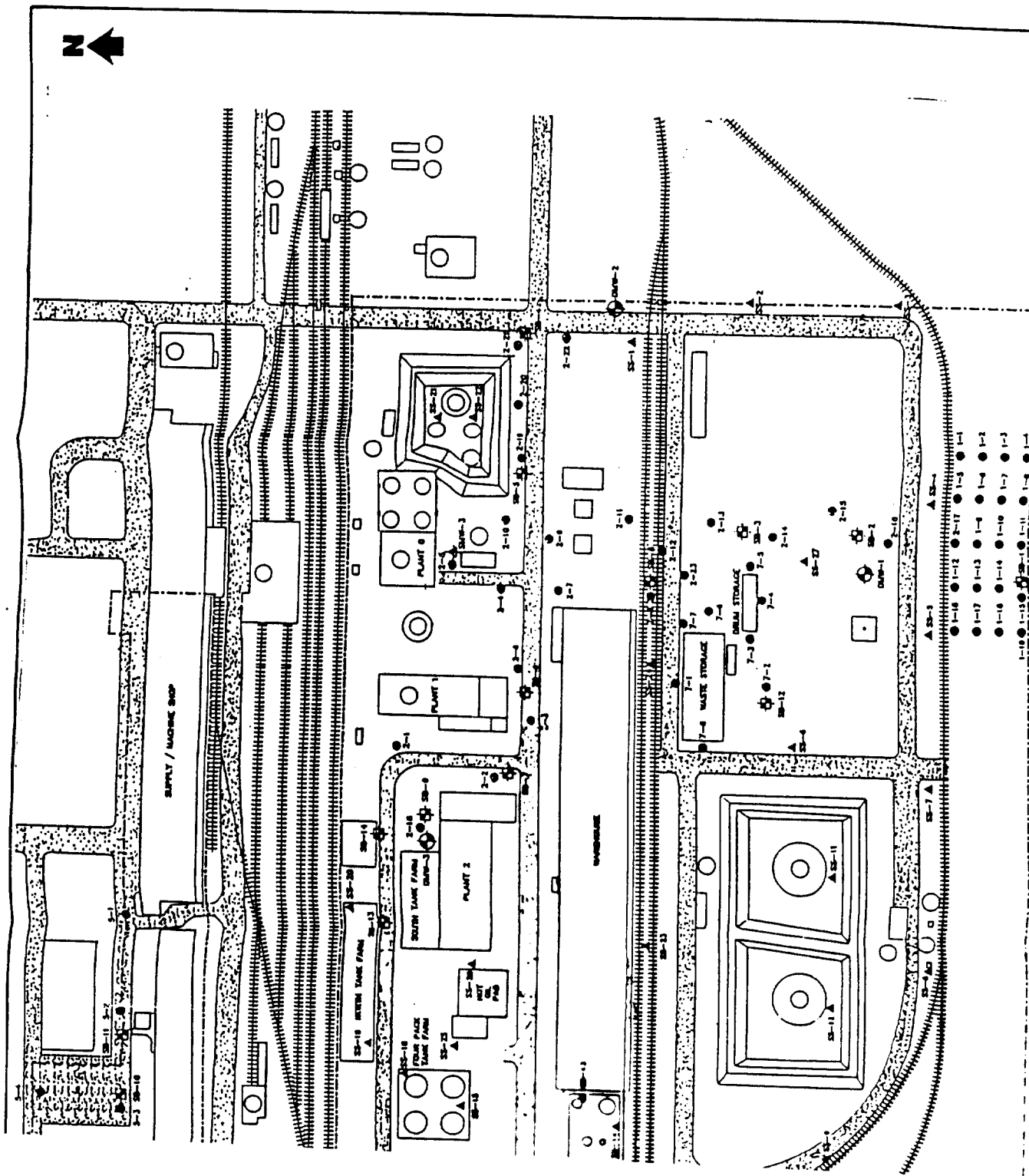


production well were sampled; these wells were MW-1S, MW-2S, MW-3S, MW-4D, MW-5S, MW-6S, MW-6D, TW-1, TW-2, TW-4, TW-5, and TW-6. Deep groundwater was sampled during the RI on June 26, 1992, from the on-site production well. The well was sampled at depths of 310, 350, 370, 420, 590, 725, and 800 feet below ground surface. Samples were analyzed for VOCs and major anions. Groundwater sample results indicated contamination by VOCs, semivolatile compounds, and metals.

Surface soil sampling was conducted during the RI. A total of 15 composite and 15 discrete samples were collected in the southern portion of the site (Figure 2-4). The composite samples were analyzed for VOCs, semivolatiles, metals, and PCBs. The discrete samples were analyzed for VOCs. The results, included in Appendix A, indicate contamination by VOCs, semivolatiles, and metals.

### **2.2.3 Allied Signal Sampling**

In October and November 1992, Allied Signal conducted soil, groundwater, and surface water sampling as part of a Phase 2 environmental site assessment. Soil and groundwater sampling was conducted in the central section of the site occupied by the Koch chemical plant (Figure 2-8). Soil samples were collected in October 1992 during the Allied Signal study. Soil samples consisted of 13 soil borings, 31 surface soil samples, and three samples from shallow monitoring wells. During the Allied Signal study, upper shallow groundwater sampling was conducted on October 7, 1992, and November 2, 1992. Eight existing wells, located in the Warsaw Formation (Figure 2-8), were sampled. Also during the Allied Signal study, lower shallow groundwater sampling was conducted on October 9, 1992. Samples were collected from DMW-1, DMW-2, and DMW-3 (Figure 2-8). Surface water samples included samples from Koch's NPDES permitted outfall and storm water runoff. Soil and groundwater sample results indicated contamination by VOCs, semivolatile compounds, and metals. Surface water sample results indicated low concentrations of metals and organics. One sample also contained levels of 1,2-DCA and TCE that exceeded KALs. This investigation produced the highest lead concentration (5,390 mg/kg) in soil of any of the studies cited in this risk assessment. That sample was taken at SS-13 (Figure 2-8).



JAYHAWK SITE  
GALENA, KANSAS

FIGURE 2-8  
ALLIED SIGNAL SAMPLE LOCATIONS

### 2.3 BACKGROUND SAMPLING

Surface water, sediment, soil, and groundwater background samples were taken during the sampling activities of the RI. Background surface water samples SW-1 through SW-6 (Figure 2-3) were collected upstream of the site in Spring River. Background sediment samples SD-1 through SD-3 also were collected upstream of the site (Figure 2-3). PRC is only using data from the Jayhawk site RI for background concentrations. The two background groundwater wells, identified as north well and south well, were located west of the site and near each other (Figure 2-7).

### 2.4 DATA EVALUATION

PRC evaluated data from Allco (Weston 1991), the RI (CH2M Hill 1992), Allied Signal (1992), the PA (KDHE 1990), and other reports described in the RI. All available data was evaluated based on quality control criteria contained in EPA guidance (EPA 1990a). As a result of the data validation process, PRC determined that the following data could be used in the quantitative evaluation:

- Groundwater results from the RI, from the Allied Signal site assessment, and from the Allco site assessment.
- Soil results from the RI, Allied Signal, and Allco reports.
- Surface water results from the RI and Allied Signal reports.
- Sediment results from the RI report.

The sampling design for the RI soil sampling was random while the designs for the property transfers were focused on areas of potential contamination. Although the designs were different PRC, after consultation with KDHE, chose to use all three data sets because they were the best available data sets.

Surface soil samples used for this risk assessment were divided into three groups based on the spatial distribution of the samples detected by three different groups. One group of samples was collected during the RI and is from the undeveloped southern portion of the facility, Area B (Figure 2-9). The second group of soil samples was taken from the active portion of the site and was taken by Allied

Signal as part of the property transfer activities, Area A. The third group of soil samples was collected during a site assessment conducted by Allco/Weston as part of a property transfer activity, Area C. PRC used data from soil samples taken from the top 6 inches reported from the RI and the top two feet of soils from the Allied Signal and Allco reports.

The following five sections detail other matters concerning how data was evaluated to determine chemicals of potential concern for the risk assessment.

#### 2.4.1 Sample Results

As stated above, PRC used the surface soil, subsurface soil, ground water and surface water results to determine the contaminants of concern and the potential exposure point concentrations. All chemicals that were identified in media at least once was included in the universe of chemicals to be considered for inclusion as a chemical of concern.

EPA guidance (EPA 1989a) suggests that a reasonable maximum concentration (RME) be identified for each chemical that will be included as a chemical of concern. PRC in conjunction with KDHE and the Jayhawk site group established a practical to be determining that RME. The value that represented the RME was the 95 percent upper confidence limit. PRC used the procedures described in EPA 1989a and Rillsert 1987 for calculating the RME. Prior to any calculations, the data was transformed by natural logarithms, to make the data fit a normal distribution. In calculating the UCL values a series of assumptions were made and these are listed below.

1. Half the detection limit was used for chemicals that were not detected. If half the detection limit was higher than the maximum detected concentration detected than the highest value detected was used, this included J coded values (see below).
2. When sample data was estimated by the laboratory (J coded), the given value was used instead of half the detection limit.
3. When samples were diluted, the undiluted values were used for all but the chemical causing the dilution.

4. Total xylenes were used by summing the m, o, and p xylenes where applicable.
5. The depth of the soil borings was not known for the data in Area A, but it was assumed all groundwater samples taken from these borings were in the upper shallow aquifer.

The results of these calculations are found in Appendix A.

#### **2.4.2 Duplicate Results**

In accordance with EPA guidance, the results of duplicates were averaged. When multiple analyses were presented for a single sample, PRC used the mean detected value.

#### **2.4.3 Comparison with Background Levels**

The following background samples were collected during the RI:

- Five soil samples (Figure 2-6), SS16001, SS17001, SS18001, SS19001, and SS20001
- Six surface water samples from two locations (Figure 2-3), SW01, SW02, SW03, SW04, SW05, and SW06
- Three sediment samples (Figure 2-3), SD01, SD02, and SD03
- Two groundwater samples (Figure 2-7), north well and south well

Because VOCs are not naturally occurring substances, no VOCs were excluded from the risk assessment based on background comparison. Chemicals that were detected in a particular medium and sample area but not in the corresponding background samples were automatically included as chemicals of potential concern without a statistical background comparison. Also, metals detected at three times the mean background levels were considered constituents of concern.

#### 2.4.4 Data Qualifiers

Contract laboratory program (CLP) qualifiers and codes attached to analytical data by laboratories were evaluated. In general, data with qualifiers that indicated uncertainties in concentrations but not in identification are included in the risk assessment. Data with qualifiers that indicate uncertainties in chemical identification (that is, qualifiers "A" and "R") were dropped from the quantitative risk assessment.

Analytes detected in blank samples were evaluated. Sample results were considered in the quantitative risk assessment if they were present at concentrations that exceeded 10 times the maximum concentrations of common laboratory contaminants or five times the concentrations of other blank contaminants.

#### 2.4.5 Uncertainty

There are three major areas of uncertainty associated with the data used in this risk assessment. The first is that three different studies are being used. The second is that the objectives of the studies caused a different sampling approach to be taken. The third is the inclusion of all chemicals detected on site as a chemical of concern. These uncertainties are discussed below.

The fact that data was collected during three different studies conducted by three different groups leads to an increase in the uncertainty of the data especially when the data is aggregated. There are several reasons for the increase in uncertainty. First, the sampling methodologies used by each group were not identical, nor were the samples handled in the same manner before being analyzed. Secondly, the three groups used three different laboratories. Although the methodologies used were similar, laboratories analyze samples differently and this can cause differences in analytical results. Lastly, the samples were taken over a 3-year period. Seasonal variations of some data can occur. All these uncertainties can cause the estimated environmental concentration of a specific media to be underestimated or overestimated.

There are uncertainties associated with any sampling design used to support a risk assessment, and some designs have a greater impact on the uncertainty. The objective of both the Allied Signal and

Allco studies was to determine if contamination existed on site and at what levels. In this type of study, samples are taken at areas of highest industrial activity and areas with a higher probability of releases. With this type of sample design, one would expect that exposure concentrations generated from this data may overestimate concentrations of a media. The approach used during the RI was to develop a sampling plan that applied a random design specially for the soil sampling, which is preferred for risk assessments. This should give a better estimate of the contaminant concentrations in areas of exposure. However, it is possible that the design can miss areas of high contamination such as swales or drainage areas. This was the case with the RI, and this may have caused an underestimation of the potential exposure concentrations.

The Baseline Risk Assessment evaluated all chemicals detected at least once in groundwater or soil. Several chemicals, as shown in Appendix A, exhibited a low frequency of detection (e.g., five percent or less based on a minimum of 20 samples for a given medium). Inclusion of chemicals detected at a frequency of five percent or less may lead to an overestimate of risk as the presence of these chemicals may be the result of artifacts in the data due to sampling, analytical, or other problems. Chemicals detected at a frequency of five percent or less may not be related to site operations or disposal practices.

## 2.5 CHEMICALS OF POTENTIAL CONCERN

The data was reviewed to determine whether it was greater than background data as described in Section 2.4.2 and whether it could be considered valid as described in Section 2.4.3. The list of chemicals that met these criteria were included in a list of chemicals of potential concern (COPC). It should be noted that PRC, under the direction of KDHE, did not use frequency of detection as a means to reduce the number of COPCs. If a chemical was identified at least once by any of the three studies, it was included as a COPC. This COPC list also was used for the ecological risk assessment outlined in Chapter 6. The full list of organic and inorganic chemicals identified as COPCs are presented in Tables 2-1 and 2-2.

TABLE 2-1

**CHEMICALS OF POTENTIAL CONCERN AT THE JAYHAWK SITE**  
**ORGANIC CHEMICALS**

ORGANIC CHEMICALS	SOILS	GROUNDWATER
1,1-DICHLOROETHANE		•
1,1-DICHLOROETHENE		•
1,2-DICHLOROETHANE	•	•
1,2-DICHLOROETHENE	•	•
1,1,1-TRICHLOROETHANE	•	•
1,2-DICHLOROBENZENE		•
1,3-DICHLOROBENZENE		•
1,4-DICHLOROBENZENE		•
2,4-DIMETHYLPHENOL		•
2-BUTANONE		•
2-CHLOR-1,3-BUTADIENE		•
2-HEXANONE		•
2-METHYLHAPHTHALENE	•	•
2-METHYL PHENOL		•
2,4,5-TRICHLOROPHENOXYACETIC ACID		•
4-CHLOROANILINE	•	•
4-METHYLPHENOL	•	•
ACENAPHTHENE	•	•
ACETONE	•	•
ANTHRACENE	•	
BENZO (a) ANTHRAECENE	•	
BENZO (a) PYRENE	•	
BENZO (b) FLUORANTHENE	•	
BENZO (g,h,i) PERYLENE	•	
BENZO (b) FLUORANTHENE	•	
BENZYL ALCOHOL	•	
BENZENE	•	•
BIS (2-ETHYLHEXYL) PHTHALATE	•	•
CARBAZOLE	•	
CARBON DISULFIDE	•	
CARBON TETRACHLORIDE		•
CHLOROBENZENE	•	•
CHLOROFORM		•
CRESOLS (MXP)	•	
CHRYSENE	•	
DI-N-BUTYLPHTHALATE	•	•
DI-N-OCTYL PHTHALATE	•	



TABLE 2-1 (Continued)

CHEMICALS OF POTENTIAL CONCERN AT THE JAYHAWK SITE  
ORGANIC CHEMICALS

ORGANIC CHEMICALS	SOILS	GROUNDWATER
DIBENZO (a,h) ANTHRACENE	•	
DIBENZOFURAN	•	
DIETHYL PHTHALATE		•
ETHYLBENZENE	•	•
FLUORANTHENE	•	
FLUORENE	•	•
HEXACHLOROBENZO-P-DIOXIN	•	
HEXACHLOROIBENZOFURANS	•	
IDENO (1,2,3-cd) PYRENE	•	
ISOPHORANE	•	
METHYLENE CHLORIDE	•	•
NAPHTHALENE	•	•
PENTACHLORODIBENZO-P-DIOXIN	•	
PENTACHLOROPHENOL	•	•
PHENANTHRENE	•	
PHENOL	•	•
POLYCHLORINATED BIPHENYLS (AROCOR 1254)	•	
PYRENE	•	
STYRENE		•
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	•	
TETRACHLORODIBENZO-P-DIOXIN	•	
TETRACHLOROETHENE		•
TOLUENE	•	•
TRANS-1,2-DICHLOROETHENE		•
TRICHLOROETHENE	•	•
VINYL CHLORIDE	•	•
XYLENES (TOTAL)	•	•

TABLE 2-2

CHEMICALS OF POTENTIAL CONCERN AT THE JAYHAWK SITE  
INORGANIC CHEMICALS

INORGANIC CHEMICALS	SOILS	GROUNDWATER
ALUMINUM	•	•
ARSENIC	•	
BARIUM	•	•
BERYLLIUM	•	
CADMIUM	•	•
CALCIUM	•	
CHROMIUM	•	
COBALT	•	•
COPPER	•	
CYANIDE	•	•
IRON	•	•
LEAD	•	•
MAGNESIUM		•
MANGANESE	•	•
MERCURY	•	
NICKEL	•	•
NITRATE/NITRITE	•	•
POTASSIUM	•	•
SELENIUM		•
SILVER	•	
SULFATE	•	
SULFIDE	•	
SULFUR	•	
TIN	•	
VANADIUM	•	
ZINC	•	•

## CHAPTER 3

### EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to estimate the type and magnitude of chemical intakes for each complete exposure pathway. An exposure assessment is a qualitative or quantitative evaluation of the frequency, duration and route of exposure. Sections 3.1, 3.2, and 3.3 qualitatively document the physical setting of the Jayhawk site, the populations that could be potentially exposed to site contaminants, and the exposure pathways related to the site, respectively. Section 3.4 quantitatively estimates chemical intakes for potentially exposed populations. Section 3.5 identifies uncertainties, and Section 3.6 summarizes the exposure assessment.

#### 3.1 PHYSICAL SETTING

The physical setting of the Jayhawk site is described in reports produced by Weston (1991), Allied Signal (1992), and CH2M Hill (1992). The following sections include a description of the surface water hydrology and geology from those reports.

##### 3.1.1 Physiography

The topography in Cherokee County ranges from 328 meters above mean sea level (MSL) (1,000 feet) in the southeast to approximately 249 meters MSL (760 feet) in the southwest portion of the county (Weston 1991). The Jayhawk site is of low relief except for lowlands that were developed by erosion caused by Shawnee Creek and the Spring River. Both of these waterways flow south.

East of Spring River is the Ozark Highland area. This area is typified by hilly timberland. West of Spring River is the Cherokee Prairie area which comprises most of Cherokee County and is largely sloping broad flats and lowlands (Weston 1991).

### 3.1.2 Geology

The geology of the Jayhawk site is described in Weston's "Groundwater Investigations and Proposed Remedial Action," done in 1991. Most of the following description of the site geology was taken from Section 3.1 of that report unless noted (Weston 1991).

#### 3.1.2.1 Unconsolidated Sediments

Weston's drilling program encountered unconsolidated sediments that ranged from 13.5 to 21 feet (4.4 to 6.9 meters) in thickness, that generally increased in thickness toward the northeast. The first soil horizon was 6 feet thick (2.6 meters) or less, and was noted to be composed of silt with traces of fine sand with abundant red and black staining. The underlying soil horizon was variable and considered either a fine to medium gravel and silt with abundant red staining or a fine to medium sand with traces of silt and some red staining. This zone was within the water table.

#### 3.1.2.2 Shallow Bedrock

The shallow bedrock Weston encountered during its drilling program included the Warsaw Formation and the Burlington-Keokuk Formation. These formations were reported to be 7 feet and 135 feet (2.3 and 44.3 meters) thick, respectively, and to be separated by an unconformity marked by significant fracturing and clay infilling. The full thickness of the Burlington-Keokuk Formation was not penetrated during Weston's investigation. A cross-section of the bedrock encountered through coring during installation of the Jayhawk Production well in 1941-42, as reported by Weston, is provided as Figure 3-1.

Weston reported that the Warsaw Formation consists of light and dark colored cherty limestone. The base of this formation also contains flint and glauconitic clay. This Warsaw Formation was reported to be heavily weathered and fractured to at least 24 feet (7.9 meters) and extended to approximately 28 feet (9.2 meters) below the surface. It was also noted that a 1- to 2-foot (0.31 to 0.61 meters) glauconitic clay layer was encountered from 19 to 21 feet (6.2 to 6.9 meters) which was believed to mark the base of the Warsaw Formation (Weston 1991).

System	Sub System	Series	Formations	Thickness (feet)	Beds and Members	Lithologic Character
Carboniferous	Mississippian	Meramecian	Warsaw limestone	15	-	Soil, Gravel, and residual chert
				7		Light and dark chert brown limestone
			Burlington - Keokuk limestone	135		Buff or pale brown limestone and light gray chert. Chert is often brown spotted or mottled oolitic limestone near the top. Lower 15' limestone dark brown, coarse crystalline limestone.
					Grand Falls	Light gray, pale brown, and glassy chert. Some cotton rock layers of limestone and dolomite.
			Reeds springs limestone	128		Dark and light brown limestone and dark gray, blue gray, and dove gray chert. Dark brown dolomite.
			St. Joe limestone	22		
			Northview Shale	5		Greenish Limestone
			Compton limestone	2		Silty greenish calcareous shale
			Cotter dolomite	105		Fine texture dark gray limestone
					Swan Creek	Gray to brownish gray dolomite, with light gray and white chert and sandy dolomite. Light brown oolite and oolitic chert near top.
Ordovician		Kinderhookian	"Atricle Group"	Open hole completion		Fine grained sandstone
						Dark brown and blue - gray and finely crystalline dolomite with some brown chert.
			Jefferson City dolomite	300		
			Roubidoux	155	Upper sandstone	Light gray, fine grained sandy dolomite with two beds of water-bearing sandstone
					Lower sandstone	
			Gasconade dolomite	20		Gray and blue - gray crystalline dolomite with chert

JAYHAWK SITE  
GALENA, KANSAS

FIGURE 3-1  
STRATIGRAPHIC COLUMN FROM  
JAYHAWK PRODUCTION WELL

Weston also reported that the Burlington-Keokuk Formation generally consists of gray to tan limestone, dolomite, and chert with abundant fractures oriented vertically and horizontally. These fractures were often partially filled with glauconitic clay or calcareous or siliceous precipitate. Dissolution features indicated water transmission at all Weston's boring locations. The coring of MW-1D recovered brecciated limestone below 39 feet (12 meters). This limestone was extremely porous and showed evidence of pyrite mineralization and dissolution features indicating water transmissivity.

Finally, Weston's investigation of the shallow bedrock stated that a Kansas Geological Survey interpretation of an electric log conducted on the Allco production well noted that electrical signatures of highly porous zones were identified from 65 to 110, from 290 to 305, and from 375 to 400 feet (21.3 to 36.1, 95.1 to 100.1, and 123.0 to 131.2 meters). Weston concluded that the brecciated zone it encountered may be stratigraphically related to the porous zone identified by the electric log at 65 feet (21.3 meters).

#### **3.1.2.3 Deep Bedrock**

When Weston investigated the deeper bedrock below the Jayhawk site, it found that the bedrock was composed of limestone and chert of Mississippian and Ordovician age. It was reported that the Allco production well penetrated the Cotter, Jefferson City, Roubidoux, and Gasconade Formations, which are Ordovician age. It was also noted that the Roubidoux Formation is the primary water-bearing formation for the supply well. The top of this formation is about 705 feet (215 meters) below MSL and is generally 155 feet (47 meters) thick. The Roubidoux Formation contains two water-bearing sand members. These members are 14.8 and 24.9 feet (4.5 meters and 7.6 meters) thick and are composed of medium- to coarse-grained quartz sand. The remaining rock of the Roubidoux Formation is a brown and gray dolomite with light gray to light blue chert.

The electric log, conducted on the supply well after its completion, provided information on the porosity and degree of saturation of the bedrock that was penetrated (Weston 1991). The porous zones were identified from 65 to 110 feet, from 290 to 305 feet, and from 375 to 400 feet (21.3 to 36.1 meters, 95.1 to 100.1 meters, and 123.0 to 131.2 meters). The electric log indicates that the Jefferson City Dolomite is fractured or consists of several different lithologic beds having different

resistivity signatures. They are probably water producing. The log of the Roubidoux Formation indicates that of the two sand units, the lower unit, which is 24.9 feet (7.6 meters) thick, is probably the more productive.

### **3.1.3 Hydrology**

The trend of flow for both the unconsolidated sediments and the shallow bedrock groundwater aquifers is to the southeast. The shallow bedrock groundwater has an average linear velocity from 0.0431 feet/day (0.013 meters/day) to 0.080 feet/day (0.024 meters/day). The average linear velocity of the overburden groundwater could not be calculated according to the groundwater investigation by Weston (1991).

### **3.1.4 Surface Water**

The Jayhawk site, located in the Spring River Valley, is situated between the south-flowing Spring River, to the east, and its tributary Shawnee Creek, to the west. The confluence of the two is approximately 1 mile south of the site.

Most surface water runoff from the plant site is discharged to Spring River either directly through NPDES permitted outfalls (002 and 003) or indirectly through storm water sewers to the 120-acre oxbow lake then to outfall 001.

During periods of high river stage, flooding of an area east of the 120-acre lake has been reported. A flood hazard study of the site indicated that a record flood which would inundate part of the plant would crest at or below an elevation of 822.5 feet (CH2M Hill 1992).

### **3.1.5 Climate**

The climate of Cherokee County is characterized by large daily and annual variations in temperature. Winters are cold because of frequent outbreaks of polar air; the cold temperatures prevail from December to February. Warm summer temperatures last for about 6 months every year. They

provide a long growing season for the crops commonly grown in the county. Spring and fall are relatively short.

Cherokee County is commonly in the path of a current of moisture-laden air from the Gulf of Mexico. Precipitation is heaviest late in spring and early in summer. Rain often falls during late-evening or nighttime (USDA 1985).

In winter the average temperature is 37.1° F, and average daily minimum temperature is 26° F. In summer the average temperature is 77.7° F, and the average daily maximum temperature is 89.3° F. The total annual precipitation is 40.52 inches. Of this 27.91 inches, or 69 percent, usually falls from April through September.

Tornadoes and sever thunderstorms strike occasionally. These storms are local in extent and brief, so risk of damage is small. Hail falls during the warmer part of the year, but hailstorms are infrequent and of local extent.

The average seasonal snowfall is 10.4 inches. On the average, 11 days of the year have at least 1 inch of snow, but snow cover generally does not last more than 7 days in succession.

The sun shines 69 percent of the time possible in summer and 55 percent in winter. The prevailing wind is from the south. Average wind speed is highest, 11 miles per hour, in March and April (USDA 1985).

### **3.2 POTENTIALLY EXPOSED POPULATIONS**

Allco, Allied Signal, and UTC currently have operations on site property (CH2M Hill 1992). Access to the site is controlled by a 6-foot fence that surrounds the site and by guards at the gate to the site. Land around the site is mainly used for agricultural production(CH2M Hill 1992).

The site is bordered by Spring River on its east and south and by Shawnee Creek on the west. Alternate U.S. 69 Highway runs north to south about 1.25 miles west of the site (CH2M Hill 1992).



A chemical plant lies north of the site (CH2M Hill 1992). The remainder of the area around the site is used for agriculture.

The nearest community is Galena, Kansas, about 1 mile southeast of the site (KDHE 1990). According to the 1990 census, the population of Galena was 3,308. Riverton, Kansas, is located about 3 miles south of the site along Alternate U.S. 69 Highway (CH2M Hill 1992). Well inventories completed during the RI for the Jayhawk site and the Galena subsite indicated that 54 groundwater wells are located within approximately 2 miles of the site. Seven water supply wells are located just outside the 2-mile radius of the site. Forty-six groundwater wells are located east of Spring River. One private shallow domestic well is located about 1.5 miles south-southwest of the site (CH2M Hill 1992).

Discussions of potentially exposed populations that are in the vicinity of the Jayhawk site and that were considered for this risk assessment follow in Sections 3.2.1 through 3.2.10.

### **3.2.1 On-Site Trespassers**

Although the site is fully enclosed by a fence, on-site trespassers may be exposed to contaminated soils. Trespassers are assumed to be adults who enter the site infrequently for short periods of time. Trespassers also include site workers who do not normally work outside but may become exposed when walking outside during break activities. Small children are not considered as trespassers because currently no residences are nearby.

### **3.2.2 Off-Site Populations**

Off-site populations may be exposed. Contaminant migration to off-site soils could result in direct contact exposures, while contaminant migration to groundwater and surface water could result in ingestion, inhalation, and dermal contact. No data exists, though, to confirm that this migration has occurred. The closest residences are located near the nearest domestic groundwater well about 1.5 miles southeast of the site (CH2M Hill 1992)

### 3.2.3 On-Site Workers

Allco employs 33 on-site workers that are exposed to contaminated soils 250 days of the year. The number of employees and type of work occurring on-site include the following (CH2M Hill 1993). The number of hours per week of potential exposure to soils for each employee are provided in parentheses:

- Three Guards (9.6)
- Three Mechanics (3.2)
- One Electrician (3.2)
- One Instrument Technician (3.2)
- Thirteen Operators (1.3)
- One Operations Director (0.75)
- One Manufacturing, VP (0.50)
- Two QC Laboratory Technicians (2.5)
- Two Dishwashers (5)
- One Laboratory Supervisor (1)
- One Pilot Plant Operator (8)
- One Pilot Plant Engineer (0.5)
- Two Project Engineers (1.6)
- One Purchasing Analyst (0.5)

Allied Signal employs 126 employees of which 18 to 20 operators each work outside about 20 hours per week.

It was assumed that there will be no significant changes in work patterns during the calculated exposure period. Under the present work patterns, workers from each of three different areas - Areas A, B, and C - only work in their respective areas. Therefore, they are only potentially exposed to contamination in their areas. It was also assumed that no special worker protection equipment would be used to prevent exposure to contaminated soils. PRC acknowledges that there are existing regulations that require an operating facility to provide its workers with appropriate protection from unnecessary exposure to contamination. If appropriate protective equipment is provided to the workers, this would minimize exposure to site contaminants and therefore minimize the associated risks. The purpose of the inclusion of the workers is to understand the potential risks if no action is taken by the operating facility to minimize exposure.

#### **3.2.4 Future On-Site Workers**

Future workers at the site may be exposed to contaminated soils and groundwater. It was assumed for this risk assessment that the site would be redeveloped in the future for industrial use. The entire property, Areas A, B, and C, would be under the control of one operator. It also was assumed that the construction may occur with no site contaminant remediation.

#### **3.2.5 Future On-Site Residents**

After consultation with KDHE, it was assumed that the site would not be developed as a residential site. This assumption was based on several factors. First, the remote location of the site does not make it a prime candidate for residential development. Second, the property is currently being used for industrial and commercial activities and this is not expected to change in the foreseeable future. Lastly, the deed to the property has had restrictions placed on it that state the property may only be used for industrial or commercial activities in the future, and this will not be allowed to change. Therefore, future on-site residents were not included as a potentially exposed population.

#### **3.2.6 Groundwater Users**

Populations in the area that use groundwater domestically may be exposed to contaminants that migrate from the site. The Jayhawk site RI and the Galena Subsite RI together identified 54 groundwater wells in the vicinity of the site. Forty-six of these wells are on the eastern side of Spring River and upgradient from the site. Seven wells south of the site are more than 2-miles from the site and one domestic, shallow well is located 1.5 mile southeast of the site. A deep well is located on the site. It is not presently used for consumption but is used for showering. Thus inhalation and dermal contact pathways were considered for water from this well.

#### **3.2.7 Surface Water Users**

Downgradient surface water users could be exposed to contaminants that may migrate from the site. The nearest drinking water intake is on the Baxter River, about 5 miles downstream of the site, which is the receiving stream for Spring Creek.

### **3.2.8 Recreational Surface Water Users**

Populations that use downgradient surface waters for recreational purposes may be exposed to contaminants that migrate from the site. Exposure may occur through direct contact with surface water and sediments, or ingestion of surface water during recreational use. Potential recreational uses of Shawnee Creek west of the site and of the oxbow lake are limited. Still, older children (ages 7 to 15) and adults could come in contact with stream surface waters and sediments during hiking and exploratory activities.

### **3.2.9 Fish Consumers**

Contaminants transported by groundwater or overland flow into the Spring River may affect area fisheries, resulting in exposure to persons consuming contaminated fish. Therefore, those who may eat fish were considered as a potentially exposed population. However, significant commercial and recreational fisheries are not reported in the site area.

### **3.2.10 Subpopulations of Potential Concern**

For this site, subpopulations of potential concern are limited to children and pregnant women who may be exposed to contaminants that have migrated off site into soil, groundwater, or surface water. However, no schools, daycare centers, hospitals, nursing homes, or retirement communities were observed in the site vicinity.

## **3.3 IDENTIFICATION OF EXPOSURE PATHWAYS**

Primary contaminant sources at the Jayhawk Site consisted of spills, discharges to sewers, land disposal, and tank or pipeline leaks (CH2M Hill 1992). Each pathway was evaluated further in the exposure assessment to determine if the pathway is complete, that is, if the pathway comes into contact with a receptor. The exposure point concentrations should represent areas where the contaminant concentration in contact with a receptor is, or is predicted to be, the greatest.

Exposure pathways are evaluated in the following subsections with exposure point concentrations estimated for those pathways that are complete. Monitoring data are used when available to document a complete exposure pathway and its exposure point concentrations. Monitoring data provide an estimate of the current exposure point concentrations at the site. Exposure point concentrations determined from monitoring data assume that the concentration will remain constant for the exposure period.

It should be noted that the sampling design for the RI soil sampling was random while the designs for the property transfers were focused on areas of potential contamination. Although the designs were different PRC, after consultation with KDHE, chose to use all three data sets because they were the best available data sets. The uncertainties associated with the data are detailed in Section 2.7.5.

### 3.3.1 Soil Exposure Pathways

The quantitative data indicates that complete pathways exist for soil ingestion, dermal contact, and inhalation of particulates by current workers and trespassers. Complete pathways for soil ingestion, dermal contact, and inhalation of particulates by future workers were also identified. The worker pathway is complete based on current site usage. The trespasser pathway is assumed to be complete by using a conservative approach. The Spring River which borders the site may attract trespassers. Security provisions for some portions of the site are currently in place but may not be in the future. Future worker's exposure is assumed to be complete since no significant change in worker habits are anticipated except that exposure frequency may increase.

Monitoring data are used to estimate the RME exposure point concentration for both the current and future use scenarios. Contaminants in the soil may be subject to a number of processes affecting their concentrations. The contaminants may bind to soil particles. The soil particles may then migrate either through surface water runoff or through larger pore spaces in the subsurface. Contaminants that do not bind to soils may migrate vertically into deeper soils and then into the groundwater or may migrate with surface water runoff from the site. Such migration would decrease the concentration of the contaminants in surface soils with time. For this risk assessment, a conservative assumption is made that contaminant concentrations in the soils will remain constant over time.

### 3.3.2 Air Exposure Pathways

Potential pathways for current and future workers and trespassers were considered for this risk assessment. On-site concentrations of contaminants are potentially released to the air in fugitive dusts.

For these pathways, the upperbound confidence level concentrations of contaminants found are used as RME point concentrations for worker and trespasser receptors. The air modeling assumes that on-site soils are available for disturbance from the wind. Particulate emissions resulting from on-site excavation by workers, which is not part of the modeled releases, could result in higher predicted concentrations of contaminants in the air due to increased exposed surface areas and the activities of the equipment. This, therefore, could cause higher potential risks. This factor is noted in the discussion of uncertainty.

### 3.3.3 Groundwater Exposure Pathways

At present, complete pathways exist for dermal contact and inhalation exposure for groundwater. PRC assumed for future exposure that complete pathways will exist for ingestion, dermal contact, and inhalation exposure for groundwater. Ingestion may occur through groundwater consumption, and dermal contact and inhalation exposures may occur through the use of groundwater for showering. The vertical and horizontal extent of two xylene groundwater plumes were determined in the RI. Low levels of xylene contamination have been reported at 800 feet below MSL (CH2M Hill 1992). Contamination of the groundwater has occurred in three depth zones. The upper shallow and lower shallow zones contain a variety of organic contaminants, including at least one light nonaqueous phase liquid (LNAPL) plume of xylene. The thickness of this LNAPL plume has not been reported. The deep zone contains 1,2-DCA and xylene.

Currently, groundwater from the deep zone is only used for nonpotable purposes (CH2M Hill 1992). According to the Jayhawk site's RI, the poor water quality of the shallow aquifer has been recognized by other studies. However, one domestic user of shallow groundwater was identified approximately 1.5 miles south of the site (CH2M Hill 1992). A conservative assumption was made that a hypothetical future industrial operator could drill a well in the upper shallow and lower shallow

aquifer. Additionally, the water presently used by the workers for nonpotable purposes on the site could be used for potable purposes, including ingestion, in the future. Because previous sampling at the site has shown a significant difference in the contamination detected in shallow and deep groundwater, exposure to estimated shallow and deep groundwater concentrations were evaluated separately.

The groundwater exposure concentrations were obtained using by combining the results from the various sampling events and determining RME concentrations for each groundwater level. PRC reviewed the data and identified the following monitoring wells for each of the three groundwater levels:

- Upper shallow wells (Warsaw Formation)
  - MW-1S through MW-7S
  - SMW-1 through SMW-3
  - MW-1D through MW-7D
  - TW-1 through TW-6
  - RW-01 through RW-06
- Lower shallow wells (Burlington-Keokuk Formation)
  - DMW-1 through DMW-3
- Jayhawk production well (open hole from the Cotter Dolomite Formation to the Gasconade Dolomite Formation)

The RME exposure point concentrations for groundwater ingestion and dermal contact routes are presented in Appendix A. The procedures used to estimate the RME concentrations during showering are presented in Appendix B.

#### 3.3.4 Surface Water Users Exposure Pathways

Release of groundwater contaminants to the Spring River has not been documented by groundwater monitoring between the location of the xylene plumes and the river. In addition, surface water sampling results did not detect any significant increase in contaminants at or downstream of the site

Therefore, all surface water pathways are considered incomplete and were not quantitatively evaluated.

### 3.3.5 Summary of Exposure Pathways Quantified in This Assessment

Complete exposure pathways and potentially affected populations are listed below. These pathways will be carried through the quantitative risk assessment. Section 3.4 incorporates exposure point concentrations compiled in Appendix A into equations that estimate chemical intakes for the pathways of concern.

- Current and future on-site soils
  - Long-term workers
  - Trespassers
- Groundwater
  - Current and future long-term workers
- Air
  - Long-term workers
  - Trespassers

## 3.4 QUANTIFICATION OF CHEMICAL INTAKES

Exposure is defined as the contact of an organism with a chemical or physical agent. The human receptors identified above were assessed quantitatively to determine the magnitude of potential chemical exposures, which is the amount of a chemical available at human exchange boundaries (that is, skin, lungs, gut) during some specific time. A general equation for calculating chemical-specific exposures for populations and exposure pathways is recommended by EPA 1989a. The components of this equation are presented in Section 3.4.2 below. The calculated intakes are expressed as the amount of chemical at the human exchange boundary and available for absorption. The calculated intakes used for this risk assessment are not equivalent to an absorbed dose, which is the amount of a chemical actually absorbed into the bloodstream (EPA 1989a).



These chemical intake equations determine lifetime average daily intake (LADI) values and chronic exposure values. These intake values then can be used to assess lifetime exposures to chemicals with linear non-threshold responses (for example, cancer responses), or to assess long-term chronic exposures to noncarcinogens. The exposure values express the repeated and prolonged exposure periods that potentially result in carcinogenic or chronic noncarcinogenic health effects. These exposure periods were assumed for most pathways at the Jayhawk site, where continuous exposures via air, soil, and groundwater were assumed.

The upper-bound cancer risk was estimated by multiplying the LADI by a toxicity factor that estimates the cancer potency of a specific chemical. This toxicity factor was determined by the 95 percent confidence limit of the linear slope factor of the dose-response function (that is, the cancer potency factor). Because the slope factor is typically based on an administered dose, exposure is normally expressed as an administered dose rather than an absorbed dose, as noted above. In the same way, noncarcinogenic risk is estimated by dividing the chronic exposure intake value by a toxicity factor that estimates the dose at which chronic health effects should not occur. These concepts are discussed further in Chapter 4.0.

Averaging time variables in Equations 3-1 and 3-2 were used to express exposure in a way that makes it comparable to the dose-response relationship. The averaging time value used to determine the LADI was the lifetime over which the exposure was averaged. For carcinogens, this should represent the average life expectancy of the exposed population. An average figure of 70 years is suggested for the lifetime of men and women (EPA 1991a). For chronic noncarcinogenic effects, the averaging time is the actual period of exposure to the contaminants. A period of 25 years for maximum case exposures is assumed for occupational receptors (EPA 1991a).

A body weight variable in Equations 3-1 and 3-2 was used to calculate total exposure and should reflect the average weight of the exposed population during the time over which exposure occurs. If the exposure occurs continuously throughout an individual's life or only during the adult stages, using an adult average weight of 70 kilograms (kg) provides sufficient accuracy (EPA 1991a).

The standard exposure equations are adapted to each pathway of concern in the following subsections. Section 3.4.1 identifies standard exposure parameters that are applicable. Section 3.4.2 introduces

exposure estimation methods. Pathway-specific parameters and exposures are identified in Section 3.4.3. Exposure parameters represent upper bound (that is, 90 or 95th percentile or maximum values) estimates of exposure conditions within each pathway. The reference for each value is presented. Standard EPA default exposure assumptions and reference documents are used for each pathway.

#### 3.4.1 Exposure Parameter Assumptions

RMEs used to estimate chemical intakes for each route of exposure are included in Table 3-1. The pathway-specific discussions in Section 3.4.3 describe these assumptions in more detail and define pathway-specific assumptions.

#### 3.4.2 Exposure Estimation Methods

The foregoing assumptions were used in combination with site-specific data to estimate a range of chemical exposures that could be used in the risk characterization. The RMEs were calculated based on the upper 95 percent confidence limits of mean concentrations and 95th or maximum percentile values for contact rate, exposure frequency, and exposure duration when data were available (EPA 1989a).

In each case, a different expression was used to estimate exposure for carcinogenic and noncarcinogenic effects. For cancer risk assessments, exposure is averaged over body weight and lifetime as follows:

$$\text{LADI} = \frac{\text{Total Exposure}}{\text{Body Weight} \times \text{Lifetime}} \quad (3-1)$$

where

$$\text{LADI} = \text{Lifetime average daily intake in milligrams per kilograms per day (mg/kg/day)}$$

For noncarcinogenic effects, exposure is in units of milligrams per kilograms per day and is averaged over body weight and the time over which exposure actually occurs:

$$\text{Chronic exposure} = \frac{\text{Total Exposure}}{\text{Body Weight} \times \text{Averaging Time}} \quad (3-2)$$

TABLE 3-1 (Continued)

REASONABLE MAXIMUM EXPOSURE FACTORS  
FOR RESIDENTIAL, OCCUPATIONAL,  
AND TRESPASSER PATHWAYS

PATHWAY	OCCUPATIONAL SCENARIOS		FUTURE TRESPASSER SCENARIO
DERMAL CONTACT WITH SOIL (Continued)	Current (Adults Only)	Future (Adults Only)	Adults Only
	5,000 cm <sup>2</sup> /event	5,000 cm <sup>2</sup> /event	2,500 cm <sup>2</sup> /event
	25 years	25 years	24 years
	70 kg	70 kg	70 kg
DERMAL CONTACT WITH WATER	Current	Future	Not Applicable (NA)
	0.25 hr (bathing)	0.25 hr (bathing)	NA
	250 days/year (bathing)	250 days/year (bathing)	NA
	20,000 cm <sup>2</sup>	20,000 cm <sup>2</sup>	NA
Exposure Duration	25 years	25 years	NA
Body Weight	70 kg	70 kg	NA
INHALATION OF VOLATILES WHILE SHOWERING	Current	Future	Not Applicable (NA)
	0.6 m3/hr	0.6 m3/hr	NA
	0.25 hr	0.25 hr	NA
	250 days/year	250 days/year	NA
Exposure Duration	25 years	25 years	NA
Body Weight	70 kg	70 kg	NA

TABLE 3-1

REASONABLE MAXIMUM EXPOSURE FACTORS  
FOR RESIDENTIAL, OCCUPATIONAL,  
AND TRESPASSER PATHWAYS

PATHWAY	OCCUPATIONAL SCENARIOS		FUTURE TRESPASSER SCENARIO
	Current (Adults Only)	Future (Adults Only)	
WATER INGESTION			Not Applicable (NA)
Consumption Rate	NA	1 L/day	NA
Exposure Frequency	50 days/year	250 days/year	NA
Exposure Duration	25 years	25 years	NA
Body Weight	70 kg	70 kg	NA
SOIL & DUST INGESTION			Adult Only
Ingestion Rate	Current	Future	Adult Only
Exposure Frequency	50 mg/day	50 mg/day	100 mg/day
Exposure Duration	50 days/year	250 days/year	10 days/year, 8 hours/day
Body Weight	25 years	25 years	24 years
	70 kg	70 kg	70 kg
INHALATION			Adults Only
Inhalation Rate	Current	Future	Adults Only
Exposure Frequency	2.5 m <sup>3</sup> /hour	2.5 m <sup>3</sup> /hour	10.4 m <sup>3</sup> /day
Exposure Duration	50 days/year 8 hours/day	250 days/year 8 hours/day	10 days/year
Exposure Duration	25 years	25 years	24 years
Body Weight	70 kg	70 kg	70 kg
DERMAL CONTACT WITH SOIL			Adults Only
Adherence Factor	Current	Future	Adults Only
	1.0 mg/cm <sup>2</sup>	1.0 mg/cm <sup>2</sup>	1.0 mg/cm <sup>2</sup>
Exposure Frequency	50 events/year	250 events/year	10 events/year

Total exposure can be expanded as follows (EPA 1990b):

$$\text{Total exposure} = \text{Contaminant Concentration} \times \text{Contact Rate} \times \text{Exposure Duration} \quad (3-3)$$

Contaminant concentration is the concentration of the contaminant in the medium (air, water, or soil) having contact with the body. These concentrations are defined as exposure point concentrations.

The contact rate refers to the rate of inhalation, ingestion, or dermal contact. For example, the ingestion contact rate is simply the amount of water or soil containing the contaminant that an individual ingests during some specific period.

The exposure duration is the length of time over which the receptor comes into contact with the contaminant. Factors such as the length of time a person lives in an area and time spent indoors vs. outdoors affect the exposure duration. When these parameter levels remain constant over time, they are substituted directly into the exposure equation. When they change with time, a summation approach is needed to calculate exposure. In either case, the exposure duration is the length of time exposure occurs at the concentration and contact rate specified by the other parameters in the equation.

Exposure to contaminants can be expressed as a total amount, an exposure rate, or as a rate normalized to body mass. Exposure estimates derived as a rate normalized to body mass are summarized in Section 3.4.3 for each exposure pathway.

### 3.4.3 Exposure Scenarios

The following six exposure scenarios were defined during this risk assessment:

#### Scenario 1: Direct ingestion of on-site surface soils

Long-term workers and site trespassers are the potentially exposed population in this exposure pathway. It was assumed for this risk assessment that a long-term worker incidentally ingests some amount of contaminated soil during each work day. A soil ingestion rate for occupational exposure is typically estimated at 50 milligrams (mg) of soil per day (EPA 1991a). This is representative of the

long-term worker scenario. It also is assumed typically that the current worker will have an exposure frequency of 50 days per year and that future workers will have an exposure frequency of 250 days per year, both for a period of 25 years (EPA 1991a).

The trespasser scenario assumes that adults can ingest soils during activities at the site. Children were not considered as trespassers because of the distance away from current residences and schools. A soil ingestion rate of 100 mg of soil per day is assumed for adults (EPA 1991a). An average body weight for an adult was estimated at 70 kilograms (EPA 1990b). An assumption was made that a trespasser may stay on site no more than 8 hours, a total of 10 times per year over a 24 year period. Eight hours was the chosen duration because there is not evidence that longer term trespassing may take place on the site (for example, from sporting activities). Eight hours was arbitrarily chosen as the length of time a trespasser may take to pass across and explore the site. The 24 years was also an arbitrary value based on the length of time that one would reside in a specific location. PRC assumed that this category also would include office personnel at the site that may periodically walk the site.

To calculate the LADI resulting from incidental ingestion of on-site soils containing carcinogens, the following equation is used:

$$LADI = \frac{(IR) (C) (EF) (ED) (CF)}{(BW) (AT)} \quad (3-4)$$

where:

- IR = soil ingestion rate (50 mg per day for a long-term on-site worker; 100 mg per day for an on-site trespasser)
- C = concentration of contaminant in soil (chemical specific, mg/kg)
- EF = exposure frequency (10 days/year for trespassers, and 250 days/year for workers)
- ED = exposure duration (25 years for workers; 24 years for trespassing adults)
- CF = 1E-06 kg/mg
- BW = body weight (70 kg for adults)
- AT = averaging time (70 years x 365 days/year = 25,550 days)

For calculating chronic exposure resulting from incidental ingestion of on-site soil to evaluate noncarcinogenic effects, the following equation is used:

$$\text{Chronic exposure} = \frac{(\text{IR}) (\text{C}) (\text{EF}) (\text{ED}) (\text{CF})}{(\text{BW}) (\text{AT})} \quad (3-5)$$

where:

$$\text{AT} = \text{averaging time [ED (years) x 365 days/year]}$$

The other factors are the same as in the equation for carcinogens.

### Scenario 2: Dermal contact with soils

Long-term workers and on-site trespassers are the potentially exposed populations in this exposure pathway. The following exposure parameters are specific to the direct contact route: surface area available for contact, soil-to-skin adherence factors, and absorption factors.

Both current and future on-site workers, such as maintenance employees, may be exposed to soil contaminants by dermal contact with soil and dust during construction activities. Dermal exposure may occur on the hands, legs, arms, neck, and head. A conservative assumption is made that 25 percent of the total body surface area is available for exposure (EPA 1992a). The default value for the 50th percentile total adult body surface area is 20,000 square centimeter (cm<sup>2</sup>), resulting in an available surface area of 5,000 cm<sup>2</sup> for workers (EPA 1992). The assumed exposure duration is the same time period as that for soil ingestion. Exposure frequency is assumed to be one event per day.

PRC also assumed that the workers would not use any worker protective equipment to minimize the exposure to soils. The assumption assures that a reasonable maximum exposure is evaluated. Current exposures may in fact be less.

The amount of soil that adheres to exposed skin is another parameter necessary for calculating exposure. Reported studies identify a range of possible soil adherence values, all with associated uncertainties. A soil adherence rate of 1.0 milligrams per square centimeter (mg/cm<sup>2</sup>) of skin was assumed as a reasonable upper value (EPA 1992a).

Absorption factors (ABS) are used to reflect desorption of the chemical from soil and the absorption of the chemical across the skin and into the blood stream. Because chemical-specific ABS factors for all site contaminants are not available in EPA documentation (EPA 1992), ranges of ABS are estimated for the three major chemical classes. These values are based on the available toxicology data and reflect the contaminant's physical and chemical properties. For VOCs, the ABS range from 10 to 25 percent; for semivolatile compounds, including pesticides, the ABS range from 1 to 10 percent; and for inorganic compounds, the ABS range from 0.1 to 1 percent (Ryan and others 1987). These ranges provide a means for more accurately estimating direct contact exposure with soils. The maximum ABS were used for this assessment.

For the trespasser scenario, the above-mentioned exposure parameters are assumed, with the following exceptions:

- Ages 16 to 40 are grouped into the adult category; exposure duration of 24 years.
- Exposure is assumed to occur in the summer months and for adults 25 percent of 20,000 cm<sup>2</sup> (or 5,000 cm<sup>2</sup>) is assumed to be exposed (EPA 1992).

The exposure time, frequency, and duration for the trespasser also is discussed in the soil ingestion scenario above.

To calculate LADI resulting from dermal contact with soil, the following equation is used for carcinogens:

$$LADI = \frac{(C) (CF) (SA) (AF) (ABS) (EF) (ED)}{(BW) (AT)} \quad (3-6)$$

where:

- C = contaminant concentration in soil (chemical-specific in mg/kg)
- CF = 1E-06 kg/mg
- SA = surface area available for contact (5,000 cm<sup>2</sup>/event for workers, and 5,000 cm<sup>2</sup>/event for adult trespassers)
- AF = soil-to-skin adherence factor (10 mg/cm<sup>2</sup>)



ABS	=	absorption factor (percent of chemical in soil absorbed/event) 0.25 for volatiles 0.10 for semivolatiles and pesticides 0.01 for inorganics
EF	=	exposure frequency (50 events/year for current workers 250 events/year for future workers, and 10 events/year for trespassers)
ED	=	exposure duration (24 years for adult trespassers, 25 years for workers)
BW	=	body weight (70 kg for adults)
AT	=	averaging time (70 years x 365 days/year = 25,550 days)

For noncarcinogens, the following equation is used to calculate exposure resulting from dermal contact with soil:

$$\text{Chronic exposure} = \frac{(C) (CF) (SA) (AF) (ABS) (EF) (ED)}{(BW) (AT)} \quad (3-7)$$

where:

$$AT = \text{averaging time [ED (in years) x 365 days/year]}$$

All other factors are the same as in the equation for carcinogens.

### Scenario 3: Volatile and Particulate Inhalation

In this scenario, human receptors are potentially affected by volatile and particulate air emissions from the site. Exposure point concentrations were determined for the site area and the property line of the nearest residence. Estimated particulate emissions were assumed to be in the respirable range (i.e., <10 micrometers [ $\mu\text{m}$ ]). It also was assumed that 100 percent of the particles inhaled would be retained in the lung.

Current workers were assumed to be exposed for 8 hours a day, 1 day a week over a 50-week period as described in the soil ingestion scenario above. Future workers were assumed to be exposed for 8 hours a day, 5 days a week, over a 50-week period. The inhalation rate for workers was assumed to be 2.5 cubic meters per hour. This represents a reasonable worst-case outdoor inhalation rate for

an adult highly active for 50 percent of the time and moderately active for 50 percent of the time (EPA 1990b).

For trespassers, the age groups, body weights, exposure time, and exposure frequency identified in the soil ingestion scenario above were assumed. The hourly inhalation rate was assumed to be 1.3 m<sup>3</sup>/hour, which is reasonable for the light to moderate activity of walking over an open field (EPA 1990b).

To calculate LADI for volatile and particulate contaminants, the following equation is used for carcinogens:

$$\text{LADI} = \frac{(C) (IR) (EF) (ED)}{(BW) (AT)} \quad (3-8)$$

where:

- C = chemical concentration in air (chemical-specific, mg/m<sup>3</sup>)
- IR = inhalation rate (2.5 m<sup>3</sup>/hour for workers; and 10.4 m<sup>3</sup>/day for trespassers)
- EF = exposure frequency (8 hours/day for 50 days/year for current workers and 8 hours/day for 250 days/year for future workers, and 8 hour/day for 10 days/year for trespassers)
- ED = exposure duration (25 years for current and future workers)
- BW = body weight 70 kg for adults
- AT = averaging time (70 years x 365 days/year = 25,550 days)

For noncarcinogens, the following equation is used to calculate exposures resulting from inhalation of particulate or volatile contaminants:

$$\text{Chronic exposure} = \frac{(C) (IR) (EF) (ED)}{(BW) (AT)} \quad (3-9)$$

where:

- AT = averaging time [ED (years) x 365 days/year]

The other factors are the same as those defined in the equation for carcinogens.

#### Scenario 4: Ingestion of Contaminated Groundwater

Ingestion of contaminated groundwater in the site area was considered a complete pathway for future on-site workers. A default value of 1 liter of water consumed per day from the contaminated aquifer was assumed for future workers (EPA 1990b). It was further assumed that the exposure duration would be 250 days a year for future workers with 25 years of exposure (EPA 1991a).

The LADI for ingestion of carcinogenic chemicals in groundwater is calculated as follows:

$$\text{LADI} = \frac{(C) (CR) (ED) (EF)}{(BW) (AT)} \quad (3-10)$$

where:

- C = concentration of contaminant in water (chemical-specific, mg/L)
- CR = water consumption rate (1 liter per day for on-site workers)
- ED = exposure duration (25 years for adults)
- EF = exposure frequency (250 days/year)
- BW = body weight (70 kg for adults)
- AT = averaging time (70 years x 365 days/year = 25,550 days)

Exposure estimates for the noncarcinogenic effects of contaminants were calculated using the following equation:

$$\text{Chronic exposure} = \frac{(C) (CR) (ED) (EF)}{(BW) (AT)} \quad (3-11)$$

where:

- AT = averaging time [ED (years) x 365 days/year]

The other factors are the same as those defined in the equation for carcinogenic effects of contaminants.

#### Scenario 5: Dermal Contact with Contaminated Groundwater

Scenario 5, like scenario 4, assumes that the groundwater is currently being used by on-site workers or that future workers will use groundwater. Dermal exposure may occur during showering or bathing. The following exposure parameters are specific to the direct contact route: surface area available for contact, dermal permeability factors, and exposure frequency.

Whole body exposure was assumed for adults for bathing and showering. The total surface area default value of 20,000 cm<sup>2</sup> was assumed for adults (EPA 1992). The exposure time for bathing or showering was assumed to be 15 minutes per day (EPA 1992). Exposure frequency was assumed to be 250 days per year for the current and future workers, and the number of years of exposure assumed was 25 years.

Dermal permeability factors estimate the potential for transport of a chemical across the skin barrier into the blood stream. Chemical-specific factors are used if available in EPA documentation (EPA 1992). Otherwise, the permeability factor for water, 1.3E-03 centimeters per hour (cm/hr), is used (EPA 1992).

The equation for calculating LADI to carcinogens in groundwater from direct contact while showering is as follows:

$$LADI = \frac{(C) (SA) (PC) (ET) (EF) (ED) (CF)}{(BW) (AT)} \quad (3-12)$$

where:

- C = contaminant concentration in groundwater (chemical-specific, mg/L)
- SA = surface area of skin contacted (20,000 cm<sup>2</sup> for workers)
- PC = permeability factor (chemical-specific, or for water 1E-03)

ET	=	exposure time (0.25 hr/day)
EF	=	exposure frequency (250 days/year)
ED	=	exposure duration (25 years for workers)
CF	=	1E-03 L/cm <sup>3</sup>
BW	=	body weight (70 kg for adults)
AT	=	averaging time (70 years x 365 days/year = 25,550 days)

For evaluating noncarcinogenic effects, the following equation is used to calculate exposure resulting from dermal contact with groundwater while showering:

$$\text{Chronic exposure} = \frac{(C) (SA) (PC) (ET) (EF) (ED) (CF)}{(BW) (AT)} \quad (3-13)$$

where:

$$AT = \text{averaging time [ED (years) x 365 days/year]}$$

All other factors are the same as in the equation for carcinogens.

The resulting exposures are expressed as absorbed dose rather than administered doses (e.g., intake). This is because permeability factors reflect movement of the chemical across the skin into the blood stream, resulting in an absorbed dose treatment. EPA (1989a) recommends that adjustments be made to match the dermal exposure estimates (expressed as absorbed dose) with the toxicity values (expressed as administered dose). These adjustments were not made in this risk assessment, the resulting uncertainty is discussed in Section 3.5

#### Scenario 6: Inhalation of Groundwater Contaminants

Scenario 6, like scenario 4, assumes that the groundwater is currently being used by on-site workers or that future workers will use groundwater. Inhalation exposures may occur during showering because of the volatilization of organic compounds.

The method used to estimate air concentrations of organic compounds during showering is contained in Appendix B. An inhalation rate of 0.6 cubic meters per hour ( $\text{m}^3/\text{hr}$ ) was assumed (EPA 1990b). An exposure frequency of 15 minutes per shower, one shower per day, and over 250 days each year for workers, was assumed (EPA 1992). Exposure duration was assumed to be 25 years (EPA 1991a).

To calculate LADI for exposure by inhalation to groundwater contaminants via showering, the following equation is used for carcinogens:

$$\text{LADI} = \frac{(C) (IR) (EF) (ED)}{(BW) (AT)} \quad (3-14)$$

where:

- C = Predicted concentrations ( $\text{mg}/\text{m}^3$ )
- IR = inhalation rate ( $0.6 \text{ m}^3/\text{hr}$ )
- EF = exposure frequency ( $0.25 \text{ hour/day}$ )
- ED = exposure duration (workers  $25 \text{ years} \times 250 \text{ days/year} = 6,250 \text{ days}$ )
- BW = body weight (average adult  $70 \text{ kg}$ )
- AT = averaging time ( $70 \text{ years} \times 365 \text{ days/year} = 25,550 \text{ days}$ )

For calculating exposure through inhalation of contaminants in groundwater during showering, the following equation is used for noncarcinogens:

$$\text{Chronic Exposure} = \frac{(C) (IR) (C) (EF) (ED)}{(BW) (AT)} \quad (3-15)$$

where:

- AT = averaging time [ $\text{ED (years)} \times 365 \text{ days/year}$ ]

The other factors are as defined in the equation for carcinogens.

### 3.5

## UNCERTAINTIES IN EXPOSURE ASSESSMENT

The exposure estimation methods described in Section 3.4 are subject to varying degrees of uncertainty. Uncertainty is inherent in the selection of exposure pathways and in the parameters used to estimate exposure doses. The degree of uncertainty generally depends on the amount of site-specific data available. This section identifies the most significant areas of uncertainty for the Jayhawk site exposure assessment and assesses the potential effect of this uncertainty.

The following sources of uncertainty are discussed below and are summarized in Table 3-2:

- Exposure pathway identification, with the assumption of RME future land uses
- Exposure parameters and assumptions
- Assumption of steady-state conditions
- Environmental chemical characterization
- Modeling procedures

#### 3.5.1

### Exposure Pathway Identification

The exposure pathways for this risk assessment were identified based on the observed and assumed activities of the local population. To the degree that actual activity patterns are misrepresented, uncertainty is introduced into the risk assessment.

In general, current activity patterns can be estimated with a good degree of accuracy. However, the activity patterns of on-site workers cannot be estimated as closely when based on existing site conditions. Therefore, all exposure estimates developed under future land use scenarios must be considered in light of the uncertainties of both future activity patterns and future land uses. Exposure doses, based on future land uses, may be overestimated. Potential exposure to fugitive dusts generated during construction activities is not evaluated for short-term workers. Therefore, total exposure for short-term workers may be underestimated.

TABLE 3-2

**AREAS OF EXPOSURE ASSESSMENT UNCERTAINTY  
AND EFFECTS ON EXPOSURE ESTIMATES**

Area of Uncertainty	May Overestimate Exposure	May Underestimate Exposure	May Over or Underestimate Exposure
<b>Exposure Pathways</b>			
Fugitive dusts resulting from site excavation are not evaluated for future short-term workers.		X	
<b>Exposure Parameters and Assumptions</b>			
Assumptions regarding population characteristics, such as body weight, surface area, life expectancy, and activity patterns, and exposure characteristics such as frequency, duration, and amount of intake, may not be representative of actual exposure conditions.			X
<b>Steady-State Conditions</b>			
Chemical concentrations measured in or estimated from the RI are assumed to remain constant and represent current and future environmental conditions.			X
<b>Environmental Chemical Characterization</b>			
Potential seasonal variations are ignored.			X
Nonrandom sample collection was used.	X		
Uniform concentrations were assumed for samples.			X
ND results were replaced with a value equal to one-half the sample detection limit.			X
Comparisons were made to background concentrations that may not actually represent background levels.			X
Both unfiltered and filtered water results were used.			X
<b>Air Modeling Procedures</b>			
Potential transformation processes are not evaluated.	X		
Assumptions used may not reflect actual conditions.			X



### 3.5.2 Exposure Parameters and Assumptions

Standard assumptions for population characteristics, such as body weight, surface area, life expectancy, and period of exposure; and exposure characteristics, such as frequency, duration, amount of intake or contact, and degree of absorption or soil adherence, may not accurately represent exposure conditions. The effect of population characteristic differences (which may overestimate or underestimate actual exposures) will probably be small when considering the potentially exposed population, because the population characteristics used in the risk assessment are based on national averages or large sample populations. However, these characteristics may not accurately represent individuals who are exposed. For example, workers may spend their entire working lives at the Jayhawk site rather than the 25-year national upper bound time or the 7-year national median length of time at one job.

Exposure characteristics depend largely on activity patterns that are not as easy to generalize as population characteristics. Uncertainties are inherent to various degrees with all exposure characteristics. Exposure doses based on the selected exposure parameters may overestimate or underestimate the actual exposure doses.

The chemical intakes determined in Section 3.4.3 represent RME conditions. Exposure factors, with the exceptions of body weight and surface areas, represent upper bound estimates of exposure conditions. RME exposure factors are provided in Table 3-1.

Exposure pathways include soil ingestion and dermal contact, vapor and particulate inhalation, and groundwater ingestion and bathing exposures (that is, dermal contact and inhalation of volatile while showering).

For dermal absorption of chemicals from soils, a variety of mechanisms alter absorption on a case by case basis. For instance, solubilization of the compound in wet soils or sweat on the skin could enhance the mobility of the compound out of the soil matrix. Investigators have found that skin hydration can increase permeability by 2 to 20 times (Michaels and others, 1975). Wet soils may also be more adherent to skin than dry soils.

The rate at which uptake from soil to skin occurs is crucial for determining whether appreciable uptake occurs during the period of time between deposition on the skin and removal by evaporation, washing, or other processes. For this assessment, exposure to soil for any period of time was assumed to yield the same dose. This assumption may over-estimate the actual dose received through dermal contact with soil.

Risk from contact with chemicals in soils are based on the perceived dermal dose of the chemical. However, what is actually estimated is the amount of chemical that crosses the stratum corneum and passes into the underlying viable tissue layer. This may not in fact equate to the actual dose as the amount of chemical that moves from viable tissue into blood and other tissues is not considered in the estimation of dermal dose.

In addition, dermal absorption of inorganics through water and soil is thought to be negligible. Metals in soil may have an absorption fraction of less than 1 percent; dermal contact with soil appears to be a concern compared to ingestion only when the percent absorbed exceeds 10 percent (EPA, 1992). Absorption of chemicals from water assumes steady-state conditions. It is unlikely that contact for a 15-minute period would result in steady-state conditions. This may over-estimate the amount of chemical absorbed.

Dermal toxicity values are not available for use in estimating risk from direct contact. Risk must be estimated using oral toxicity values that have been adjusted from administered to absorbed dose, however this does not account for response differences between oral and dermal doses. Dermal doses are not subject to first-pass hepatic metabolism before reaching the systemic circulation. The resulting dermal dose may be greater than a dose received orally, or, if the toxic effect is attributable to an active metabolite, it may be more pronounced than if received orally.

The risk associated with skin effects for locally acting toxic agents cannot be estimated from oral toxicity data. However, this risk assessment did not attempt to estimate the risks from skin effects and only estimated risks from chemicals that crossed through the skin and entered the blood stream

It should also be noted that PRC used a standard dermal absorption factor for three classes of compounds, volatiles, semi-volatiles, and metals (Ryan and others 1987). This may cause an over or

under estimation of the actual absorption. For example for 2,3,7,8 TCDD literature values for dermal absorption ranges from 0.1 to 3 percent, this could cause an over estimation of risk.

As noted in Section 3.4, EPA (1989a) recommends that adjustments be made to match the dermal exposure estimates (expressed as absorbed dose) with the toxicity values (expressed as administered dose). These adjustments require specific knowledge of the tests used to develop toxicity values for each contaminant at the site, and the percentage of the dose administered in each test that was potentially absorbed by the test organisms. Because this information is not readily available, the toxicity values were not adjusted in this risk assessment. This may result in an underestimation of actual risks, since the toxic effects observed in testing may have resulted from an absorbed dose that is smaller than the known administered dose.

### **3.5.3 Assumption of Steady-State Conditions**

Estimated exposure doses are based on an assumption of steady-state conditions. Chemical concentrations used to estimate the exposure doses are based on data from the RI (CH2M Hill 1992) and Allied Signal (1992). The inherent assumption is that current and future chemical concentrations are the same as those measured during these studies. This assumption ignores the effect of various fate-and-transport mechanisms, which will alter the composition and distribution of chemicals present in the various media, as well as the affect of possible removal or remedial actions that would reduce chemical concentrations. In general, the assumption of steady-state conditions probably may result in an overestimation of chemical concentrations and resulting exposure doses. However, it is also possible that ground water concentrations may be increasing over time and an underestimation may occur.

### **3.5.4 Environmental Chemical Characterization**

It is difficult to completely characterize the nature and extent of chemicals in the environment at the Jayhawk site. Instead, the various environmental media were sampled to estimate environmental chemical concentrations and to assess which chemicals were present as a result of chemical releases at the site. Because no sampling can completely and accurately characterize environmental conditions the exposure dose calculations will be somewhat uncertain.

Uncertainties are introduced into exposure dose calculations during collection, analysis, and evaluation of environmental chemical data. Six potentially significant areas are discussed below: (1) seasonal variations in environmental concentrations; (2) nonrandom sample collection; (3) assumption of uniform concentrations; (4) treatment of nondetection results; (5) comparison to background concentrations; and (6) use of unfiltered versus filtered sampling results.

#### **3.5.4.1 Seasonal Variations**

This risk assessment largely is based on data collected as part of the RI, on data for the assessment done by Allied Signal, and on data collected for Allco. Although the data represent the most thorough and complete sampling efforts at the site, samples representative of each season were not taken for all media. Therefore, the data do not fully reflect seasonal variations. This does not affect soil concentrations, which are unlikely to vary seasonally, but it could affect results for surface water and groundwater concentrations. Not using representative sample data for all seasons may result in an overestimation or underestimation of actual environmental concentrations and corresponding exposure doses.

#### **3.5.4.2 Nonrandom Sample Collection**

Samples were not collected randomly in the studies used for this risk assessment. Generally, sampling points were selected to identify areas of environmental chemical contamination and not to identify representative concentrations. For example, surface soil sampling locations were chosen based on information on the areas that were most likely to have soil contamination. Therefore, exposure doses based on these soil samples as well as on other nonrandom samples may overestimate actual exposure doses.

#### **3.5.4.3 Assumption of Uniform Concentrations**

Contaminant concentrations in each medium are assumed to be uniform throughout a particular exposure area based on samples taken from specific points within that area. For example, a high contaminant concentration in a sample from a "hot spot" in soil could drive the soil exposure concentration of that contaminant up for an entire area. Conversely, "hot spots" may not have been

sampled and, therefore, may not have been adequately represented in the exposure concentration for an area. Assumption of uniform concentrations may lead to overestimation or underestimation of actual exposures.

#### **3.5.4.4 Treatment of Nondetection Results**

During production of environmental statistics, nondetection results were replaced with a value equal to one-half the sample detection limit. This procedure introduces uncertainty because the sample result could be less than or greater than the substituted value. However, the procedure is more conservative than replacing these results with zero (thus assuming that a chemical would not be present even if the analysis is very sensitive). This treatment of nondetection results may result in an overestimation or underestimation of environmentally significant chemicals of potential concern.

The degree of uncertainty introduced is roughly proportional to the frequency of these results within a particular sample set. Statistics calculated from a sample set that contains a single nondetection result are less uncertain than statistics calculated from a sample set in which most results are nondetection results.

#### **3.5.4.5 Comparison to Background Concentrations**

The statistical comparison of potentially affected or downgradient samples to background samples was a significant step in identifying COPCs. Selecting appropriate background samples is critical to the accuracy and usefulness of such comparisons. For some media, such as soils, appropriate site-specific background samples were more easily identified than for others.

The statistical comparisons to background samples were not accepted simply at face value. The nature of the background samples was also considered in selecting COPCs. However, a degree of uncertainty is introduced whenever the most appropriate background samples cannot be identified and a less appropriate set of values must be used. This uncertainty may result in an overestimation or underestimation of environmentally significant chemicals of potential concern.

#### **3.5.4.6 Unfiltered Versus Filtered Results**

EPA guidance requires that exposures and risks related to groundwater be based on unfiltered results (EPA 1989a). In this risk assessment, exposure and risk calculations are based on unfiltered groundwater results (organics and inorganics) for the upper shallow aquifer and filtered results for lower shallow aquifer. Some users may in fact filter groundwater before using it for drinking purposes; others may not. Therefore, the risks based on unfiltered results may overestimate the actual risks related to metals exposure for persons who filter their groundwater. However, risks calculated using filtered groundwater results may have underestimated actual risks related to metals exposure for these people, because it is not reasonable to assume that residents will use a 0.45 micron type filter as was used to obtain the sample.

#### **3.5.5 Modeling Procedures**

Models were used to determine contaminant concentrations in outdoor air resulting from volatilization and particulate emissions from excavation and construction activities, and exposure to VOCs during showering. Numerous assumptions are included in these models. These assumptions introduce uncertainty to the degree that they do not reflect actual conditions. Use of the models may lead to overestimation or underestimation of actual environmental concentrations.

### **3.6 SUMMARY OF EXPOSURE ASSESSMENT**

RME exposure point concentrations based on soil and groundwater exposures listed in Appendix A are factored into the equations described in Section 3.4 to determine potential chemical intake. The intake values are then carried through the risk assessment steps described in the following sections to determine carcinogenic and noncarcinogenic health effects. Appendix D includes a summary of chemical concentrations, estimated intakes, and health risks.

## CHAPTER 4

### TOXICITY ASSESSMENT

This section summarizes the toxicologic basis for all chemical-specific toxicity data using available dose-response information. The section is divided into three parts. Section 4.1 presents an overview of the types of dose-response information used to characterize carcinogenic and noncarcinogenic risks at hazardous waste sites. Toxicity values including slope factors for carcinogenic effects and reference doses for noncarcinogenic effects are presented. Chemicals for which no toxicity values are available are also discussed. Section 4.2 is a brief discussion of some of the assumptions and uncertainties regarding the toxicity values used to characterize risks. Finally, Section 4.3 presents brief summaries of available toxicologic information for COPCs found at the Jayhawk site.

#### 4.1 DOSE-RESPONSE INFORMATION

In developing risk assessment methods, EPA recognizes fundamental differences between carcinogenic and noncarcinogenic dose-response variables used to estimate risks. Because of these differences, human health risk is characterized separately for the carcinogenic and noncarcinogenic effects related to chemical contaminants. Some COPCs may have both carcinogenic and noncarcinogenic effects, although in most cases EPA has published toxicity criteria for only the more sensitive type of toxic effect, supporting the most restrictive toxicological criteria.

Typically, EPA uses chronic rather than acute toxicity data in developing toxicity criteria. Acute toxicity data are derived from studies in which animals are exposed to high doses of a chemical over a short time period. In contrast, chronic exposure refers to low level exposure that occurs throughout much of a lifetime.

##### 4.1.1 Toxicity Information for Carcinogenic Effects

The key dose-response variable used in quantitative risk assessment of carcinogenic effects is the slope factor.

Typically, carcinogenicity studies are conducted at high doses. To evaluate the probability of developing cancer at the lower doses more frequently encountered by the public, the linearized multistage model is applied to the data. This mathematical model expresses excess cancer risk as a function of exposure and is based on the conservative assumption that even a single, low-dose exposure to a carcinogen may result in cancer.

From the model, the 95th percentile confidence limit of the slope from the dose-response curve is calculated. This slope factor, expressed in units of  $(\text{mg/kg/day})^{-1}$  provides a conservative estimate of the probability of cancer development from a lifetime of exposure to a particular level of a potential carcinogen. By definition, there is only a 5 percent chance that the probability may actually be higher.

Chemical-specific slope factors are multiplied by dose from a given exposure route to assess the upper bound cancer risk associated with that dose.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as belonging to one of six groups – Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals are agents for which there are sufficient data of carcinogenicity from human exposures. Group B chemicals are characterized by either limited (B1) or inadequate (B2) evidence of carcinogenicity from human exposure studies, but there is sufficient evidence of carcinogenicity from animal studies. Group C chemicals are agents for which there is limited evidence of carcinogenicity from animal studies. Group D chemicals are characterized by an inadequate carcinogenicity database. Chemicals exhibiting no evidence of a carcinogenic response in humans or animals are assigned to Group E.

#### **4.1.2 Toxicity Information for Noncarcinogenic Effects**

The key dose-response variable used in quantitative risk assessment of noncarcinogenic effects is the RfD value. The RfD (expressed in units of  $\text{mg/kg/day}$ ) for a specific chemical is an estimate with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a portion of the lifetime (EPA 1994b). It is usually based on the relationship between the dose



of a noncarcinogen and the frequency of systemic toxic effects in experimental animals or humans, and it assumes that there is a threshold below which toxic effects are not observed. The threshold of observed effects is divided by an uncertainty factor to derive an RfD that protects the most sensitive members of the population. Uncertainty factors are discussed in Section 4.2.

Once an RfD for a compound has been verified by EPA, it is used to evaluate long-term noncarcinogenic risks at the site. This "acceptable" dose is compared to the expected dose (calculated in the exposure assessment) to determine whether chronic effects might occur. If predicted exposure concentrations are below the RfD, no adverse chronic health effects are expected.

Available dose-response information for quantitative risk assessment is summarized in Tables 4-1 through 4-4 for the COPCs. Table 4-1 contains oral reference doses, and Table 4-2 lists inhalation reference doses. The EPA weight-of-evidence classifications for the carcinogens involved in this risk assessment are presented in Tables 4-3 and 4-4. Table 4-3 provides oral slope factors, and inhalation slope factors are in Table 4-4. RfD values and confidence ratings for noncarcinogens and slope factors and weight-of-evidence ratings for carcinogens were collected from the EPA Integrated Risk Information System (IRIS) database (EPA 1994a) and the EPA Health Effects Assessment Summary Tables (HEAST), Fiscal Year (FY) 1994 (EPA 1994b). It should be noted that for several chemicals, RfDs and slope factors were not provided in these documents; however, reference concentrations (RfC) and unit risk values were provided. PRC used the guidance provided in HEAST (EPA 1994b) to use these values to calculate slope factors and RfDs. When RfCs and unit risks were used, this is noted in the tables.

#### **4.1.3 Chemicals With No EPA Toxicity Values**

For some chemicals, RfDs and slope factors were available only for the oral route of exposure. For these substances, the RfDs and slope factors for the oral route of exposure were also used to estimate dermal exposure. Only inhalation RfDs and slope factors were used to estimate inhalation exposure. No route-to-route extrapolation was attempted, as specified in EPA risk assessment guidance (EPA 1989a). Because carcinogenic chemicals may also cause noncarcinogenic health effects, RfD values (where available) were compiled for carcinogenic chemicals and were used to evaluate the potential noncarcinogenic effects of carcinogens.

TABLE 4-1

## ORAL REFERENCE DOSES FOR CHEMICALS OF POTENTIAL CONCERN

Chemical	Chronic Oral RfD (mg/kg/day)	Critical Effect	Source	Uncertainty Modifying Factors <sup>a</sup>
<b>ORGANICS</b>				
1,1-DICHLOROETHANE	1.0E-01	None observed	HEAST	1,000
1,1-DICHLOROETHENE	9.0E-03	Liver damage	IRIS	1,000
1,2-DICHLOROETHENE	9.0E-03	Liver effects	HEAST	1,000
1,1,1-TRICHLOROETHANE	9.0E-02	Liver toxicity	SHRTSC	1,000
1,2-DICHLOROBENZENE	9.0E-02	None observed	IRIS	1,000
2-CHLORO-1,3-BUTADIENE	2.0E-02	Retarded growth	HEAST	100
2-METHYL PHENOL	5.0E-02	Decreased body weight and neurotoxicity	IRIS	1,000
ACENAPHTHENE	6.0E-02	Liver effects	IRIS	3,000
ACETONE	1.0E-01	Liver and Kidney effects	IRIS	1,000
ANTHRACENE	3.0E-01	None observed	IRIS	3,000
BENZYL ALCOHOL	3.0E-01	Epithelial hyperplasia	HEAST	1,000
BIS(2-ETHYLHEXYL)PHTHALATE	2.0E-02	Increased liver weight	IRIS	1,000
CARBON DISULFIDE	1.0E-01	Fetal Phytotoxicity	IRIS	100
CARBON TETRACHLORIDE	7.0E-04	Liver lesions	IRIS	1,000
4-CHLOROANILINE	4.0E-03	Proliferative spleen lesions	IRIS	3,000
CHLOROBENZENE	2.0E-02	Liver effects	IRIS	1,000
CHLOROFORM	1.0E-02	Liver lesions	IRIS	1,000
p-CRESOL	5.0E-03	Reduced weight gain, neurotoxicity	HEAST	1,000
DI-N-BUTYL PHTHALATE	1.0E-01	Increased mortality	IRIS	1,000
DIETHYL PHTHALATE	8.0E-01	Liver lesions	IRIS	1,000
ETHYLBENZENE	1.0E-01	Liver/kidney effects	IRIS	1,000
FLUORANTHENE	4.0E-02	Liver damage	IRIS	3,000
FLUORENE	4.0E-02	Blood effects	IRIS	3,000
METHYLENE CHLORIDE	6.0E-02	Liver effects	IRIS	100
NAPHTHALENE	4.0E-02	Decreased weight gain	SHRTSC	1,000
PENTACHLOROPHENOL	3.0E-02	Fetotoxicity	IRIS	100
PHENOL	6.0E-01	Reduced fetal weight	IRIS	100
PYRENE	3.0E-02	Kidney effects	IRIS	3,000
TETRACHLOROETHENE	1.0E-02	HEPA toxicity	IRIS	1,000
TOLUENE	2.0E-01	Liver/kidney weight changes	IRIS	1,000
2,4,5-Trichlorophenoxy acetic acid	1.0E-02	Weight effects	IRIS	1,000
4,4'-DDT	5.0E-04	Liver lesions	IRIS	100
2,4-DIMETHYLPHENOL	2.0E-02	Nervous system effects	IRIS	1,000
DI-N-OCTYL PHTHALATE	2.0E-02	Increased weight of liver and kidney	HEAST	1,000

TABLE 4-1 (Continued)  
ORAL REFERENCE DOSES FOR CHEMICALS OF POTENTIAL CONCERN

Chemical	Chronic Oral RfD (mg/kg/day)	Critical Effect	Source	Uncertainty Modifying Factors <sup>a</sup>
ISOPHORONE	2.0E-01	Kidney lesions	IRIS	1,000
STYRENE	2.0E-01	Red blood cells and liver effects	IRIS	1,000
4-METHYL PHENOL	5.0E-03	Central nervous system	IRIS	1,000
XYLENES (TOTAL)	2.0E+00	Hyperactivity, lower weight	IRIS	100
INORGANICS				
ARSENIC	3.0E-04	Skin effects	IRIS	3
BARIUM	7.0E-02	Increased blood pressure	IRIS	3
BERYLLIUM	5.0E-03	None observed	IRIS	100
CADMIUM	1.0E-03/5.0E-04 <sup>b</sup>	Kidney damage	IRIS	10
CHROMIUM	1.0E+00	No effects	IRIS	100
COPPER	3.7E-02	Gastrointestinal irritation	HEAST	--
CYANIDE	2.0E-02	Thyroid effects, weight loss	IRIS	100
MANGANESE	1.4E-01/5.0E-03	Neurological effects	IRIS	1
MERCURY	3.0E-04	Kidney effects	HEAST	1,000
NICKEL	2.0E-02	Decreased body and organ weights	IRIS	300
NITRATE	1.6E+00	Methemoglobinemia	IRIS	1
NITRITE	1.0E-01	Methemoglobinemia	IRIS	10
SELENIUM (selenous acid)	5.0E-03	Selenosis	IRIS	3
SILVER	5.0E-03	Argyria	IRIS	3
TIN	6.0E-01	Liver and kidney lesions	HEAST	100
VANADIUM	7.0E-03	None observed	HEAST	100
ZINC	3.0E-01	Anemia	IRIS	3

Notes:

- No data available
- IRIS Integrated Risk Information System, On-Line Data Base, 1994
- HEAST Health Effects Assessment Summary Table, 1994
- SHRISC Superfund Health Risk Technical Support Center, 1994

<sup>a</sup> Uncertainty modifying factor for chronic oral RfD  
<sup>b</sup> Food/water

TABLE 4-2

## INITIALATION REFERENCE DOSES FOR CHEMICALS OF POTENTIAL CONCERN

Chemical	Chronic Inhalation RfD (mg/kg/day)	Critical Effect	Source	Uncertainty Modifying Factors
<b>ORGANICS</b>				
1,1-DICHLOROETHANE	1.0E-01	Kidney damage	HEAST	100
1,2-DICHLOROBENZENE	5.7E-02	Decreased weight gain	HEAST	1,000
1,1,1-TRICHLOROETHANE	2.9E-01	Hepatotoxicity	HEAST	1,000
2-BUTANONE	2.9E-01	Decreased fetal birth weight	IRIS	1,000
CARBON DISULFIDE	2.9E-03	Phytotoxicity	HEAST	1,000
CHLOROBENZENE	5.7E-03	Liver and kidney effects	HEAST	10,000
2-CHLORO-1,3-BUTADIENE	2.9E-02	Olfactory epithelium degeneration	HEAST	300
1,4-DICHLOROBENZENE	2.3E-01	Liver effects	IRIS	100
ETHYLBENZENE	2.9E-01	Developmental toxicity	IRIS	300
METHYLENE CHLORIDE	8.6E-01	Liver toxicity	HEAST	100
STYRENE	2.9E-01	Central nervous system (CNS) effects	IRIS	100
TOXUENE	1.1E-01	CNS effects	IRIS	300
<b>INORGANICS</b>				
BARIUM	1.4E-04	Fetotoxicity	HEAST	1,000
MANGANESE	1.4E-03	Impaired neuro-behavioral function	IRIS	1,000
MERCURY	8.6E-05	Neurotoxicity	HEAST	30
Notes:				
-- No data available IRIS Integrated Risk Information System, On-Line Data Base, 1992-1993 HEAST Health Effects Assessment Summary Table, 1992				

TABLE 4-3

## ORAL SLOPE FACTORS FOR CHEMICALS OF POTENTIAL CONCERN

Chemical	Oral Slope Factor (mg/kg/day) <sup>-1</sup>	Weight of Evidence Classification	Type of Cancer	Source
<b>ORGANICS</b>				
1,1-DICHLOROETHENE	6.0E-01	C	Adrenal gland	IRIS
1,2-DICHLOROETHANE	9.1E-02	B2	Hemangiosarcomas, circulatory system	IRIS
1,4-DICHLOROBENZENE	2.4E-02	C	Liver	heast
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	1.5E+05	B2	Several	HEAST
4,4-DDT	3.4E-01	B2	Liver	IRIS
AROCLOP-1254	7.7E+00	B2	Liver	IRIS
BENZENE	2.9E-02	A	Leukemia	IRIS-HEAST
BENZO(A)ANTHRACENE	7.3E-01	B2	Lung/liver	EPA 1993
BENZO(A)PYRENE	7.3E+00	B2	Several	IRIS
BENZO(B)FLUORANTHENE	7.3E-01	B2	..	EPA 1993
BENZO(A)FLUORANTHENE	7.3E-02	B2	..	EPA 1993
BIS(2-ETHYLHEXYL)PHTHALATE	1.4E-02	B2	Liver	IRIS
CARBAZOLE	2.0E-02	B2	Liver	HEAST
CARBON TETRACHLORIDE	1.3E-01	B2	Liver	IRIS
CHLOROFORM	6.1E-03	B2	Kidney	IRIS
CHRYSENE	7.3E-03	B2	Liver	EPA 1993
DIBENZO(A,H)ANTHRACENE	7.3E+00	B2	..	IRIS
HEXACHLORODIBENZO-P-DIOXINS (HxCDD)	6.2E+03	B2	Hepatic tumors	IRIS
HxCDF	1.5E+04	..	..	HEAST and EPA/625/3-89/016 <sup>a</sup>
INDENO(1,2,3,c,d)PYRENE	7.3E-01	B2	Lung	EPA 1993
ISOPHORONE	9.5E-04	B2	Kidneys	IRIS
METHYLENE CHLORIDE	7.5E-03	B2	Lung/liver	IRIS
PCDD	7.5E+04	..	..	HEAST and EPA/625/3-89/016
PENTACHLOROPHENOL	1.2E-01	B2	Several	IRIS
TETRACHLOROETHENE	5.1E-02	B2	Liver	SHRTSC
TRICHLOROETHENE	1.1E-02	B2	Liver	SHRTSC
VINYL CHLORIDE	1.9E+00	A	Lung	HEAST

**TABLE 4-3 (Continued)**  
**ORAL SLOPE FACTORS FOR CHEMICALS OF POTENTIAL CONCERN**

Chemical	Oral Slope Factor (mg/kg/day) <sup>-1</sup>	Weight of Evidence Classification	Type of Cancer	Source
<b>INORGANICS</b>				
ARSENIC	1.75E+00	A	Skin	IRIS
BERYLLIUM	4.3E+00	B2	Lung	IRIS
Notes: -- No data available IRIS Integrated Risk Information System, On-Line Data Base, 1994 HEAST Health Effects Assessment Summary Table, 1994 * Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins (CDD) and Dibenzofurans (CDF) and 1989 Update.				

TABLE 4-4

## INHALATION SLOPE FACTORS FOR CHEMICALS OF POTENTIAL CONCERN

Chemical	Inhalation Slope Factor (mg/kg/day) <sup>-1</sup>	Weight of Evidence Classification	Type of Cancer	Source
<b>ORGANICS</b>				
1,1-DICHLOROETHENE	1.7E-01	C	Kidney	IRIS
1,2-DICHLOROETHANE	9.1E-02	B2	Several	IRIS
2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	1.5E+05	B2	Several	HEAST
4,4 DDT	3.4E-01	B2	Liver	IRIS
BENZENE	2.9E-02	A	Leukemia	IRIS-HEAST
CARBON TETRACHLORIDE	5.3E-02	--	Liver	HEAST
CHLOROFORM	8.1E-02	B2	Liver	IRIS
HCDD	4.55E+03	--	--	IRIS
HxCDF	1.5E+04	--	--	EPA/625/3-89/016
METHYLENE CHLORIDE	1.6E-03	B2	Liver/lungs	IRIS
PCDD	7.5E+04	--	--	EPA/625/3-89/016
TETRACHLOROETHENE	1.8E-03	B2	Leukemia	IRIS
TRICHLOROETHENE	1.7E-02	B2	Lung	SHRTSC
VINYL CHLORIDE	3.0E-01	A	Liver	HEAST
<b>INORGANICS</b>				
ARSENIC	1.5E+01	A	Skin	IRIS
BERYLLIUM	8.4E+00	B2	Lung	IRIS
CADMIUM	6.3E+00	B1	Respiratory tract	IRIS
CHROMIUM	4.2E+01	--	Lung	HEAST

Notes:

- No data available
- IRIS Integrated Risk Information System, On-Line Data Base, 1994
- HEAST Health Effects Assessment Summary Table, 1994

For some chemicals, no RfD, RfC, slope factor, or unit risk values were located in either the IRIS database or HEAST. For chemicals with no toxicity values, risks were not quantified.

#### 4.2 ASSUMPTIONS AND UNCERTAINTIES REGARDING TOXICITY VALUES

Several assumptions were made in compiling and using dose-response information for some of the COPCs. For example, only total trace metal concentrations were measured for each metal at the site, not distinct species concentrations. Consequently, the RfD for chromium III (1 mg/kg/day) was used instead of the RfD for chromium VI (0.005 mg/kg/day) to provide a more realistic estimate of potential risks associated with chromium ingestion.

RfDs and slope factors must be viewed in light of uncertainties and gaps in toxicological data. Information on toxic effects in humans is often limited to historical cases of accidental exposures. Studies must be conducted with specially bred homogenous animal species, and the results extrapolated to the heterogenous human population. The problems with this approach include the presence of sensitive subpopulations among humans and differences in physiology, target organs, metabolism, sensitivity, and detoxification capabilities between humans and animals.

In addition, high-dose, short-term animal studies may not be applicable to the low-level, long-term exposures that humans are more likely to experience. The quality of the animal study may introduce additional uncertainty.

The uncertainties discussed above are addressed by dividing the no observable adverse effect level (NOAEL) from animal studies by uncertainty factors of 10. These uncertainties are incorporated into RfDs and slope factors. Uncertainty factors are applied to data in the following cases (EPA 1989a):

- To account for variation in the general population (to protect sensitive subpopulations)
- To extrapolate the data from animals to humans
- To adjust for using an NOAEL from a subchronic, rather than a chronic study
- To adjust for using an LOAEL (lowest observable adverse effect level) instead of an NOAEL in developing an RfD.



A modifying factor ranging from 1 to 10 also is applied to the data to reflect any other uncertainty. This modifying factor is applied based upon professional opinion.

PRC used an approach that applies toxicity equivalence factors (TEF) to determine slope factors for carcinogenic polyaromatic hydrocarbons and dioxins (EPA 1989c and 1993). The basic assumption is that one chemical within each class of compounds can be used as a bench mark for the other compounds within that class. For dioxins, the bench mark is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), and to determine the slope factors for the other compounds in this group a factor is applied to the 2,3,7,8-TCDD value that reflects the toxicity of the compound relative to 2,3,7,8-TCDD. The table below shows those factors.

<u>Compound</u>	<u>TEF</u>
2,3,7,8-TCDD	1
Other TCDDs	0
2,3,7,8-PCDD	0.5
Other PCDD	0
2,3,7,8-HCDF	0.1
Other HCDF	0

The analytical data provided in this study provided specific isomer information for TCDD. The analytical data provided on the other dioxins and furans did not identify any specific isomers, therefore, PRC was not able to determine the percentage of the of the detected dioxins and furans that were the 2,3,7,8 isomers. To be health protective, PRC assumed that 100 percent of the values reported for pentachlorodibenzo-p-dioxin (PCDD) and hexachlorodibenzofurans (HCDF) were the 2,3,7,8-PCDD and 2,3,7,8-HCDF isomers. This assumption may cause an over-estimation of the risk.

PRC also applied the TEF approach for the carcinogenic polynuclear aromatic hydrocarbons. The bench mark compound for this group is benzo(a)pyrene. The table below presents the TEFs applied in this risk assessment (EPA 1993).

<u>Compound</u>	<u>TEF</u>
Benzo(a)anthracene	0.1
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenzo(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

### 4.3 TOXICITY SUMMARIES

Contaminants found at the Jayhawk site have varying effects on humans. It is never possible to predict with 100 percent certainty the effect that a given concentration of a chemical will have on a given individual because each individual reacts differently. Certain classifications of persons (such as infants or the elderly) are known to be more susceptible to contaminants of all sorts. Furthermore, the standard values presented in Section 4.1 generally involve two extrapolations: from animals to humans, and from a high dose (giving adverse effects) to a low dose. Uncertainty factors and similar devices are used to account for errors in extrapolation. Finally, the most difficult factor to estimate is the interaction among contaminants and between contaminants and other factors. Where particular uncertainties and interactions are known, these are pointed out in the individual summaries.

Brief summaries of the contaminants posing the greatest carcinogenic risk and highest hazard quotients at the Jayhawk site are provided in this section. All of the toxicity values used in risk calculations are provided in Tables 4-1 through 4-4.

#### 1,1-Dichloroethene

Commonly known as vinylidene chloride, 1,1,-dichloroethene (1,1-DCE) is used as a chemical intermediate, primarily for manufacturing polymers such as modacrylic and saran fibers. This review is based on a number of authoritative reviews including Torkelson and Rowe (1981), NLM (1990) and EPA (1984a).

The 1,1-DCE is absorbed through all routes: oral ingestion, inhalation, and dermal contact. It is extensively metabolized in the liver, primarily by oxidation and conjugation. Metabolites are excreted

in the urine, and some unchanged chemical is exhaled, especially after large doses that saturate the enzymatic pathways. A number of known interactions with other compounds exist because of the effects of 1,1-DCE and the other compound on metabolic enzymes. Species of test animals that metabolize 1,1-DCE more easily (such as mice) are more sensitive to its toxic effects.

The main effect of a single dose of 1,1-DCE is fully reversible central nervous system depression. The liquid is quite irritating to the skin, respiratory tract, and eyes; however, much of the cornea injury may be caused by the phenolic polymerization inhibitor in the commercial product. Repeated doses produce a variety of liver and kidney lesions. Eighteen animal carcinogenicity studies have been conducted, but most have been inadequate, and many reveal no increases in tumors. Because of these findings, 1,1-DCE is considered only as a possible human carcinogen. Reproductive toxicity has been observed only at doses that produce maternal toxicity. Exposure to high concentrations through inhalation sensitizes the myocardium to arrhythmias by epinephrine injection.

In acute aquatic toxicity studies, 1,1-DCE was relatively nontoxic to fish, with lethal concentration for 50 percent of the test population (LC50) values ranging from 74 mg/L for bluegill to 250 mg/L for sheepshead minnows and inland silverside. Some species are even less sensitive, with LC50 values above 700 or 800 mg/L for mysid shrimp and several algae.

### 1,2-Dichloroethane

Known commercially as ethylene dichloride, 1,2-DCA is primarily used as a chemical intermediate in the production of vinyl chloride and other chemicals and as a solvent. This review is based on a number of authoritative reviews including Torkelson and Rowe (1981) and NLM (1990).

1,2-DCA is absorbed through all routes: oral ingestion, inhalation, and dermal contact. Distribution is not well reported. 1,2-DCA is metabolized in the liver through a number of pathways, leading to a variety of products. Unmetabolized 1,2-DCA and carbon dioxide are exhaled, and other metabolites are excreted in the urine. Only traces of the chemical are excreted in the feces or incorporated into the body. These absorption processes of 1,2-DCA have not been studied in humans, and the relative importance of various pathways varies considerably between species. Therefore, extrapolating data from laboratory animals to humans is more uncertain than usual.

The main effects of acute doses are irritation at the site of contact and central nervous system depression. Large doses also produce lesions in the liver, kidney, and adrenals. Repeated doses affect the same organs, causing similar lesions and characteristic scarring. Carcinogenesis studies in rats and mice reveal that 1,2-DCA produces a variety of tumors, so it is considered a probable human carcinogen. The few reproductive studies report no adverse effects.

In limited aquatic toxicity studies, 1,2-DCA showed low toxicity, with acute LC50s in invertebrates and fish exceeding 100,000 µg/L.

### Carcinogenic Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) are generally found as a highly complex mixture in the products of incomplete combustion (coal soot, cigarette smoke, motor vehicle exhaust, and so on). This summary is based on information in the following reviews: Clement (1988), ATSDR (1987a, b, c, and d), NLM (1990) and EPA (1984b). Seventeen PAHs are included in EPA's hazardous substances list, but few are well studied. The most recent general evaluation (National Institute for Environmental Health Sciences 1989) concludes that the following PAHs detected at the Jayhawk site are probably carcinogenic:

- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(a)pyrene (BAP)
- Indeno(1,2,3-cd)pyrene
- Chrysene

The slope factor for BAP was modified by relative potency estimates presented in a study by EPA (1993).

Dermal absorption of BAP and other PAHs has been demonstrated indirectly, because toxic effects have been seen after oral and inhalation exposure. PAHs are oxidized in the liver by an enzyme, aryl

hydrocarbon hydroxylase (AHH), to the epoxide, which hydrolyses to the hydroxy or dihydroxy derivative. The metabolites are the active forms of the chemicals; variations in the formation (amount, rate, products) of these metabolites account for the different effects of the various PAHs. PAHs also cause the synthesis of greater quantities of AHH and other drug-metabolizing enzymes; therefore, simultaneous exposure to PAHs and other toxicants increases or decreases the toxicity of the other toxicants. A few nonmetabolic interactions also exist. For example, BAP increases the cardiac sensitization effects of trichloroethene. PAHs are excreted as a large variety of oxidized metabolites and conjugated metabolites, mostly through the bile into the feces.

The carcinogenic PAHs are immunotoxic; the more potent carcinogens are also more potent immunosuppressants.

PAHs have little, if any, reproductive toxicity according to the few available studies, except in peritoneal studies of BAP in rodents. Most adverse effects were nonspecific, such as decreased birth weight and reproductive performance, and were at relatively high doses. The potency of BAP as a reproductive toxicant was markedly affected by inborn differences in metabolism among various strains of mouse, emphasizing the importance of metabolism to the toxicity of these compounds.

### Methylene Chloride

Dichloromethane, commercially known as methylene chloride and methylene dichloride, is a widely used, highly volatile, nonflammable solvent, and is the least acutely toxic of the chlorinated methanes. This review is based on a number of authoritative reviews including Torkelson and Rowe (1981), EPA (1984c, 1985a, 1985b, 1987a, and 1987b), NIOSH (1986), ATSDR (1987e), and NLM (1990).

Dichloromethane may enter the body through various routes, where it is absorbed, metabolized, or excreted. It is rapidly absorbed from the lung and gastrointestinal tract. Absorption through the skin is slower and is often minimal because of volatilization. Elimination is primarily by exhalation as the parent compound or as its major metabolites, carbon monoxide and carbon dioxide. Carbon monoxide is probably responsible for a significant part of dichloromethane's toxicity.

Although dichloromethane is mildly irritating, the major acute toxic effect is central nervous system depression. Very large doses (near lethal) also produce liver, kidney, and cardiac toxicity. The nervous system is most affected by repeated doses, with common symptoms of neurasthenia and paresthesia. Other adverse effects, primarily seen in animal studies, are on the same organs as with acute doses: the liver, kidney, and heart.

Repeated animal studies have found that dichloromethane will cause tumors by inhalation and ingestion. The two reported human studies (occupational exposures) showed no excess cancer mortality, so dichloromethane is considered a "probable animal carcinogen." The few available animal studies of reproductive toxicity show effects only at doses causing gross maternal toxicity.

Little information was found on the aquatic toxicity of dichloromethane. Acute toxicity is seen at about 11,000  $\mu\text{g/L}$ .

### Polychlorinated Biphenyls

Polychlorinated biphenyls (PCB) have been extensively reviewed by a variety of organizations. In humans, the primary acute toxic effect of PCBs is chloracne. No distinctive acute effects have been reported in animals. Repeated dose toxicity in humans is known as "Yusho disease" after the residents of Yusho, Japan, who ate rice bran oil contaminated with PCBs for several months. After a latent period of several months, the victims developed chloracne, pigmentation of skin areas, visual disturbances, gastrointestinal distress, jaundice, and lethargy. Infants from exposed mothers had low birth weight and pigment blotches. Some observers have ascribed some or even most of this toxicity to the chemically related polychlorinated dibenzofurans (PCDF) in the mixture with the PCBs. These PCDFs are decomposition products of PCBs, formed in large quantities by fires involving PCBs.

PCBs are carcinogenic in some animal studies. There is some indication from occupational and Yusho exposures that PCBs are carcinogenic in humans, but this evidence is not definitive because of other, simultaneous exposures.

PCBs have reproductive toxicity, based on results of the few animal studies, the Yusho incident, a more recent similar incident in Taiwan, and a study of mothers eating PCB-contaminated fish.

Effects were similar to adult toxicity; nonspecific effects included low birth weight and spontaneous abortions or stillbirths and skin lesions. In the few studies found, PCBs have little or no mutagenicity.

### 2,3,7,8-Tetrachlorodibenzo-p-dioxin

2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD), is an unwanted by-product from the synthesis of chlorobenzenes, chlorophenols, and related compounds. It also is released in burning any chlorine-containing organic matter, so it is found in incinerator emissions and the exhausts from vehicles using leaded gasoline. Because of its notoriety, it has been extensively reviewed (EPA 1984d, ATSDR 1988a, CDC 1988, NLM 1993).

TCDD is absorbed after ingestion and through the skin; no inhalation studies are available. Once absorbed, it is concentrated in the fat and in the liver. TCDD is slowly metabolized in the liver and excreted in the feces through the bile. Its half-life in most laboratory animals is a week to a month, but in primates, including humans, the half-life is well over a year.

The only definite toxic effect which has been seen in exposed humans is chloracne, which can persist decades after exposure ends. In animal studies, TCDD is notable for extremely wide differences in potency, even among closely related species. For instance, the median lethal oral doses in guinea pigs and hamsters vary by a factor of 10,000. A total dose given at once or divided over 90 days has the same effects. The most frequently seen toxic effect in animals is a progressive loss of body weight with no distinctive symptoms. In a number of species, other effects may be seen, especially immune suppression, and liver toxicity. TCDD is a potent reproductive toxin, especially in monkeys. It is carcinogenic to laboratory rodents, causing liver tumors, thyroid tumors, and some others. Human studies have found no solid link between exposure to TCDD and tumors, primarily because of confounding exposures to other chemicals, but it is considered a probable human carcinogen based on the animal studies.

No aquatic toxicity values for TCDD were found. The few studies have been limited to showing a high bioconcentration factor, typically 3,000 to 30,000.

### Trichloroethene

TCE is a commonly used solvent, especially in dry cleaning and metal degreasing. It has been reviewed by Torkelson and Rowe (1981), EPA (1984e), NLM (1990), and ATSDR (1988b). TCE is well absorbed after inhalation and ingestion, and to some extent through intact skin. It tends to collect in fat. The compound is metabolized in the liver to a variety of metabolites, at least some of which are responsible for much of TCE's toxicity. Metabolites are excreted primarily in the urine. TCE interacts with a number of other chemicals, including ethanol, generally increasing the severity of effects of both compounds.

Acute exposures cause central nervous system depression and some irritation. TCE was once used as a surgical anesthetic, but this practice has been abandoned because of side effects, especially cardiac sensitization to the effects of the body's own control mechanisms, and liver failure, which are both sometimes fatal. Chronic dosing produces liver and kidney lesions as well as a peripheral neuritis. The chemical was found to be carcinogenic in some animal tests, but no human data are available. There is no evidence of reproductive toxicity in the few tests available.

In aquatic toxicity studies, TCE has shown acute toxicity (48- to 96-hour LC50s) at concentrations of 2 to 85 mg/L in various species. No-effect concentrations for longer exposure of *Daphia magna* have been 10 mg/L (EPA 1980; Hermens and others 1985; NLM 1990).

### Vinyl Chloride

Vinyl chloride, or chloroethene, was of little toxicological interest until 1974 when it was first reported as a human carcinogen [Torkelson and Rowe (1981); EPA (1984f); ATSDR (1988c)]. Vinyl chloride may enter the body through various routes. Once in the body, it is metabolized and excreted. It is fully absorbed after inhalation and ingestion, but little goes through the skin. It is concentrated in the liver (the site of metabolism) and kidney (the site of excretion). Vinyl chloride is oxidized to an epoxide and other reactive intermediates, which react further. These intermediates are generally believed to be the active chemical species for the specific toxic effects of vinyl chloride. Excretion is primarily in the urine as conjugates of metabolites with sulfur-containing compounds. Very small amounts are exhaled unchanged.



Vinyl chloride exhibits both acute and chronic effects. Large single doses of vinyl chloride produce central nervous system depression. Early studies of its anesthetic potential found cardiac and circulatory disturbances. Repeated low doses in workers produce a syndrome called "vinyl chloride disease." This includes acroosteolysis, Raynaud's disease, scleroderma, lung toxicity, thrombocytopenia, and liver toxicity. Chromosomal abnormalities are reported in workers. Liver toxicity seems to be the effect seen at lowest doses.

The most striking effect of vinyl chloride toxicity is the production of hemangiosarcomas, which are extremely rare tumors. These are found in the liver and occasionally elsewhere. Since this has been repeatedly confirmed in worker-exposure studies and animal studies, vinyl chloride is considered a definite human carcinogen. Some studies also have reported vinyl chloride-induced tumors in other organs, especially the brain and, after inhalation, the lungs. One rat study found that prior subchronic dosing with ethanol increased tumor incidence.

There have been reports of reproductive toxicity in exposed workers, but no adverse effects have been seen in animal studies except at quite high doses that produce nonspecific toxic effects. Epidemiological studies in the neighborhoods of vinyl chloride plants have been inconclusive.

There are no data on the aquatic toxicity of vinyl chloride. Its high volatility, with half-lives of hours in natural bodies of water, greatly decreases the possibility of any adverse effects.

Acute doses cause local irritation. Large inhalation doses may cause death from pulmonary edema. Workers exposed by inhalation also develop gastrointestinal symptoms such as nausea, vomiting, cramps, and diarrhea, and contact lesions on the skin. Repeated exposure causes pneumoconiosis, liver damage, gastrointestinal ulcers, and an increase in heart disease, which is sometimes fatal. Isolated reports of adverse reproductive effects and lung tumors in exposed workers are documented, but no conclusive studies are available.

## CHAPTER 5

### RISK CHARACTERIZATION

In this chapter, risks associated with each of the current and future land-use exposure pathways described in Chapter 3 are quantified and evaluated for individual chemicals, for multiple chemicals within specific exposure pathways, and across multiple exposure pathways, as appropriate. Carcinogenic effects are evaluated for average lifetime exposures; noncarcinogenic effects are evaluated for long-term (chronic) exposures. Subchronic noncarcinogenic effects are also evaluated for future short-term on-site workers. Risks under current land use conditions are evaluated first followed by risks under future land use conditions. The section concludes with a discussion of the uncertainties involved in risk characterization.

#### 5.1 RISK CHARACTERIZATION METHODOLOGY

The methodologies used to characterize carcinogenic and noncarcinogenic risks are discussed separately below.

##### 5.1.1 Carcinogenic Risks

For a carcinogen, a risk estimate represents the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to that carcinogen (EPA 1989a). These are termed "excess lifetime cancer risks" and are calculated using Equation 5-1:

$$\text{Upper bound excess lifetime cancer risk (risk)} = \text{LADI} \times \text{SF} \quad (5-1)$$

where

$$\begin{aligned} \text{LADI} &= \text{Lifetime average daily intake (mg/kg/day)} \\ \text{SF} &= \text{Slope factor (mg/kg/day)}^{-1} \end{aligned}$$

Risk is expressed as a probability. For example, 1E-06 translates to one additional cancer in an exposed population of one million. The slope factor in almost all cases represents an upper

95th percent confidence limit of the probability of a carcinogenic response, based on experimental animal data used in a multistage model. Therefore, the resulting risk estimate represents an upper bound estimate of the carcinogenic risk; the actual risk will probably not exceed the estimate and is likely to be lower.

As indicated on Tables 4-3 and 4-4, carcinogenic risks in this assessment were evaluated for chemicals with weight-of-evidence classifications of A, B1, B2, and C. Most available slope factors have been derived from experiments in which the route of exposure was ingestion. The resulting oral slope factors relate to the amount of substance administered per unit of time and unit of body weight. When dermal routes of exposure were considered, chronic daily intake (CDI) was expressed as absorbed rather than administered doses. To estimate carcinogenic risks for dermal routes of exposure, EPA (1989a) recommends that slope factors be adjusted to account for oral absorption efficiency. As noted in the exposure discussion in Chapter 3, these adjustments require specific knowledge of the tests used to develop toxicity values for each contaminant. Since this information is not readily available for all contaminants considered in this assessment, toxicity values were not adjusted. This could result in an underestimation of actual risks, since the toxic effects observed in testing may have resulted from an absorbed dose that is smaller than the known administered dose. However, because of the high degree of uncertainty involved in estimating risks from dermal exposure to contaminants and the conservative nature of the assumptions involved, the risks estimated for dermal exposures are more likely to have overestimated the actual risks.

According to the revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990c), carcinogenic risks from exposures at a Superfund site after remediation may range from  $1\text{E-}04$  (one cancer in an exposed population of ten thousand) to  $1\text{E-}06$  (one cancer in an exposed population of one million). A risk level greater than  $1\text{E-}04$  is considered to present a significant risk, and a level less than  $1\text{E-}06$  is considered insignificant. Risk levels between  $1\text{E-}04$  and  $1\text{E-}06$  represent EPA's opinion on what are generally acceptable levels within the target range. The terms "significant" and "insignificant" are not meant to imply acceptability; however, they help put the numerical estimates developed in this risk assessment into context. In general, a potential upper bound excess lifetime cancer risk of  $1\text{E-}06$  is used by EPA as a point of departure or a benchmark.

Within a given exposure pathway, individuals may be exposed to more than one substance. To estimate the overall carcinogenic potential for each exposure pathway, PRC followed the procedures outlined in *Guidelines for the Health Risk Assessment of Chemical Mixtures* (EPA 1986). The total upper bound excess lifetime cancer risk for each exposure pathway is estimated using Equation 5-2:

$$\text{Risk}_T = \text{Risk}_1 + \text{risk}_2 + \dots + \text{risk}_i \quad (5-2)$$

where

$$\begin{aligned} \text{Risk}_T &= \text{Total cancer risk for a given exposure pathway} \\ \text{Risk}_i &= \text{Risk estimate for the } i^{\text{th}} \text{ substance} \end{aligned}$$

The risk summation methodology is based on two primary assumptions: (1) intakes of individual substances are small and (2) the independent action of each substance is summed (no synergistic or antagonistic chemical interactions exist, and each substance causes the same effect—cancer). To the extent that these assumptions are not valid, the estimated total risk may overestimate or underestimate the actual risk.

Finally, at particular exposure points, receptors may be exposed via a number of contaminant exposure pathways. For example, under RME future land use conditions, receptors may be exposed to groundwater via a private well, to ambient air via inhalation, and to surface soil via incidental ingestion and dermal contact. The total exposure for a receptor equals the sum of the exposures via the various exposure pathways to which the receptor is exposed at a particular exposure point. The total incremental carcinogenic risk posed to a receptor via a combination of pathways is calculated using Equation 5-3:

$$\begin{aligned} \text{Total exposure point cancer Risk}_T &= \text{Risk (exposure pathway}_1) + \\ &\quad \text{Risk (exposure pathway}_2) + \dots + \\ &\quad \text{Risk (exposure pathway}_i) \end{aligned}$$

where:

$$\begin{aligned} \text{Risk (exposure pathway}_T) &= \text{risk from all exposure pathways} \\ \text{Risk (exposure pathway}_i) &= \text{risk from the } i^{\text{th}} \text{ exposure pathway.} \end{aligned}$$

Chemical-specific cancer risks are summarized in the tables in Appendix D. The nature, development, and risks of each exposure pathway combination are discussed in Sections 5.2 and 5.3.

### 5.1.2 Noncarcinogenic Risks

For noncarcinogens, the potential for individuals to develop noncancer effects is evaluated by comparing an exposure dose developed over a specific exposure period to an RfD developed over a similar exposure period. This comparison takes the form of a ratio called a hazard quotient (HQ), and is expressed in Equation 5-4:

$$HQ = E / RfD \quad (5-4)$$

where

HQ = Hazard quotient  
E = Chronic exposure (or intake)  
RfD = Reference dose

E and RfD are expressed in the same units and represent the same exposure period.

For most compounds, the RfD is expressed as an administered dose. HQ calculations are based on the assumption that both the RfD and exposure dose are expressed as an administered dose. Exposure doses for dermal routes of exposure are expressed as absorbed doses. As noted in Section 5.1.1, toxicity values are not adjusted to reflect absorption and, therefore, HQs could be underestimated. However, based on the conservative nature of the assumptions involved in the exposure and risk assessments, HQs for dermal pathways are more likely to overestimate actual risks.

An HQ exceeding 1 indicates the potential for noncarcinogenic health effects. The sum of individual HQs associated with the same target organ (described below) may exceed 1 even if no single HQ exceeds 1.

In this risk assessment, exposure doses are developed and evaluated for chronic exposure periods for residential exposure for two age groups: children ages 0 to 6 and adults 18 years or older. Thus,

exposure-period durations are 6 years and 24 years, respectively. Thirty years corresponds to the period of time during which a person is considered to be exposed to a contaminant, assuming a 70-year life. Thirty-year exposure encompasses either 30 years of an adult life (that is, 18 years and older) or 30 years of combined child and adult exposure periods (for example, 6 years and 24 years, respectively). Residents are assumed to live at a given location for 30 years (the national average upper bound time at one residence (EPA 1989a). Therefore, a chronic exposure is developed as appropriate for each age group. This approach assumes exposure at the estimated frequency for the length of each age group's exposure period. Each chronic exposure is evaluated using chronic RfDs.

Long-term exposure to workers are also considered in this assessment. As noted in Section 3.4, the exposure period is estimated at 25 years, which is based on the assumption that the worker will stay at this job for a maximum of 25 years.

As with carcinogenic substances, within a given exposure pathway, individuals may be exposed to multiple substances with noncarcinogenic health effects. To estimate the overall noncarcinogenic potential for each exposure pathway, PRC followed the procedures outlined in *Guidelines for the Health Risk Assessment of Chemical Mixtures* (EPA 1986). The total noncarcinogenic risk for each exposure pathway is estimated using Equation 5-5:

$$\text{Hazard Index (HI)} = \text{HQ}_1 + \text{HQ}_2 + \dots + \text{HQ}_i \quad (5-5)$$

where

$$\text{HQ}_i = \text{Hazard quotient for the } i^{\text{th}} \text{ substance.}$$

This summation methodology assumes that the various substances to which a receptor is exposed cause the same health effect by the same mechanism. If this assumption is incorrect, the estimated total exposure point HI may overestimate the total noncarcinogenic risk for a given exposure pathway. This methodology also assumes that when the mechanism of interaction is unknown, the assumption of adaptivity predicts reasonably well the toxicities of mixtures. If this assumption is incorrect, the HI may overestimate or underestimate the noncarcinogenic risk.

As discussed earlier for carcinogenic effects, exposure pathway combinations are developed for receptors both on and off site. The total noncarcinogenic risk posed to a receptor via a combination of pathways may be calculated using Equation 5-6:

$$\begin{aligned} \text{Total exposure point HI} &= \text{HI (Exposure pathway}_1\text{)} + \\ &\quad \text{HI (Exposure pathway}_2\text{)} + \dots + \\ &\quad \text{HI (Exposure pathway}_i\text{)} \end{aligned} \quad (5-6)$$

Chemical-specific HQ are summarized in tables contained in Appendix D. HQ and HI are discussed for specific pathways in Sections 5.2 and 5.3.

## 5.2 CURRENT LAND USE CONDITIONS

Risks under current land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below and summarized in table format. Current land use conditions considered in the risk assessment are the occupational and trespassing scenarios.

### 5.2.1 Occupational

Current occupational exposure to soils occur from individual Areas A, B, and C via inhalation of fugitive dusts, dermal contact, and incidental ingestion. Exposure to deep groundwater via dermal contact and inhalation during showers were also considered at the Jayhawk site. Future occupational exposure to soils from Areas A, B, and C combined and ingestion of deep groundwater also were considered. The soils data from the site was subdivided into three areas as described in Chapter 3. In Area A, the predicted current cancer rates, calculated using equation 5-3, are 1E-04 for ingestion, dermal contact, and inhalation of dusts combined. The main contributors toward this risk were PCBs, PCDD, and BAP through the ingestion and dermal contact routes. All hazard indices are 2.6E-02 or less, which is not a significant noncarcinogenic health threat.

Sample results from Area B predicted cancer rates of 5E-06 for ingestion, dermal contact with, and inhalation of soils. The main contributors to the risk were PCBs and BAP. The predicted HQ for these exposures are all less than or equal to 4.8E-01, which is not significant.

Sample results from Area C predicted cancer rates of  $2E-05$  for ingestion, dermal contact with, and inhalation of soils. The main contributors to the risk were arsenic, PCBs, and methylene chloride. The predicted HQ for these exposures are all less than  $2.2E-02$ , which is not significant.

The data from the subsurface soil borings was only evaluated for exposure via incidental ingestion and dermal contact. The predicted total cancer risk from these exposures is  $6E-07$ , which is not a significant risk. The predicted HQ for these exposures were less than  $1.5E-02$ , which is not a significant non-carcinogenic health threat.

Exposure to contaminants in deep groundwater to current workers occurs via two routes: dermal contact and inhalation. Dermal contact and inhalation are current exposures and ingestion is a future exposure. Both dermal contact and inhalation occur during showering. The predicted total cancer risk is  $2E-05$  with  $5E-07$  and  $2E-05$  risk occurring via the dermal contact and inhalation pathways, respectively. Most of the risk is being contributed by 1,2-DCA and methylene chloride. The predicted HQ for these exposures were less than  $7.9E-05$ , which is not a significant occupational noncarcinogenic health threat.

Contaminant-specific excess cancer risks and hazard indices for the pathways are presented in Appendix D, Tables D-1 through D-22, and D-29 through D-33 and are summarized in Table 5-1.

### 5.3 FUTURE LAND USE CONDITIONS

Risks under future land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below and summarized in table format. Future land use conditions considered in the risk assessment are occupational and residential.

#### 5.3.1 Occupational

In Areas A, B, C, and subsurface combined, the predicted future cancer rates for ingestion, dermal contact with, and inhalation of soils were  $4E-04$ . The major contributors to the cancer risk were PCDD, 2,3,7,8-TCDD, PCBs, BAP, and chromium. The predicted HQ for these exposures are all less than 1.0, which is not significant. However, the sum of the HQs for this



As discussed earlier for carcinogenic effects, exposure pathway combinations are developed for receptors both on and off site. The total noncarcinogenic risk posed to a receptor via a combination of pathways may be calculated using Equation 5-6:

$$\begin{aligned} \text{Total exposure point HI} &= \text{HI (Exposure pathway}_1\text{)} + \\ &\quad \text{HI (Exposure pathway}_2\text{)} + \dots + \\ &\quad \text{HI (Exposure pathway}_i\text{)} \end{aligned} \quad (5-6)$$

Chemical-specific HQ are summarized in tables contained in Appendix D. HQ and HI are discussed for specific pathways in Sections 5.2 and 5.3.

## 5.2 CURRENT LAND USE CONDITIONS

Risks under current land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below and summarized in table format. Current land use conditions considered in the risk assessment are the occupational and trespassing scenarios.

### 5.2.1 Occupational

Current occupational exposure to soils occur from individual Areas A, B, and C via inhalation of fugitive dusts, dermal contact, and incidental ingestion. Exposure to deep groundwater via dermal contact and inhalation during showers were also considered at the Jayhawk site. Future occupational exposure to soils from Areas A, B, and C combined and ingestion of deep groundwater also were considered. The soils data from the site was subdivided into three areas as described in Chapter 3. In Area A, the predicted current cancer rates, calculated using equation 5-3, are  $1\text{E-}04$  for ingestion, dermal contact, and inhalation of dusts combined. The main contributors toward this risk were PCBs, PCDD, and BAP through the ingestion and dermal contact routes. All hazard indices are  $2.6\text{E-}02$  or less, which is not a significant noncarcinogenic health threat.

Sample results from Area B predicted cancer rates of  $5\text{E-}06$  for ingestion, dermal contact with, and inhalation of soils. The main contributors to the risk were PCBs and BAP. The predicted HQ for these exposures are all less than or equal to  $4.8\text{E-}01$ , which is not significant.

Sample results from Area C predicted cancer rates of  $2\text{E-}05$  for ingestion, dermal contact with, and inhalation of soils. The main contributors to the risk were arsenic, PCBs, and methylene chloride. The predicted HQ for these exposures are all less than  $2.2\text{E-}02$ , which is not significant.

The data from the subsurface soil borings was only evaluated for exposure via incidental ingestion and dermal contact. The predicted total cancer risk from these exposures is  $6\text{E-}07$ , which is not a significant risk. The predicted HQ for these exposures were less than  $1.5\text{E-}02$ , which is not a significant non-carcinogenic health threat.

Exposure to contaminants in deep groundwater to current workers occurs via two routes: dermal contact and inhalation. Dermal contact and inhalation are current exposures and ingestion is a future exposure. Both dermal contact and inhalation occur during showering. The predicted total cancer risk is  $2\text{E-}05$  with  $5\text{E-}07$  and  $2\text{E-}05$  risk occurring via the dermal contact and inhalation pathways, respectively. Most of the risk is being contributed by 1,2-DCA and methylene chloride. The predicted HQ for these exposures were less than  $7.9\text{E-}05$ , which is not a significant occupational noncarcinogenic health threat.

Contaminant-specific excess cancer risks and hazard indices for the pathways are presented in Appendix D, Tables D-1 through D-22, and D-29 through D-33 and are summarized in Table 5-1.

### 5.3 FUTURE LAND USE CONDITIONS

Risks under future land use conditions associated with each of the exposure pathways described in Chapter 3 are discussed below and summarized in table format. Future land use conditions considered in the risk assessment are occupational and residential.

#### 5.3.1 Occupational

In Areas A, B, C, and subsurface combined, the predicted future cancer rates for ingestion, dermal contact with, and inhalation of soils were  $4\text{E-}04$ . The major contributors to the cancer risk were PCDD, 2,3,7,8-TCDD, PCBs, BAP, and chromium. The predicted HQ for these exposures are all less than 1.0, which is not significant. However, the sum of the HQs for this

TABLE 5-1

## SUMMARIES OF EXCESS CANCER RISKS AND HAZARD INDICES

## Current Land Use Conditions - Occupational Exposure

Medium	Exposure Pathway	Excess Cancer Risks	Hazard Indices
Soils - Area A	Incidental Ingestion	1E-05	8.5E-03
	Dermal Contact	1E-04	1.7E-02
	Inhalation of Fugitive Dust	1E-07	6.7E-04
	TOTAL	1E-04	2.6E-02
Soils - Area B	Incidental Ingestion	5E-07	6.4E-03
	Dermal Contact	5E-06	1.4E-01
	Inhalation of Fugitive Dust	7E-09	3.3E-01
	TOTAL	5E-06	4.8E-01
Soils - Area C	Incidental Ingestion	2E-06	1.5E-02
	Dermal Contact	8E-06	9.5E-02
	Inhalation of Fugitive Dust	6E-06	1.1E-01
	TOTAL	2E-05	2.2E-01
Subsurface Soils	Incidental Ingestion	4E-08	3.6E-03
	Dermal Contact	6E-07	1.1E-02
	TOTAL	6E-07	1.2E-02
Groundwater	Dermal Contact	5E-07	1.9E-05
	Inhalation - Showers	2E-05	6.0E-05
	TOTAL	2E-05	7.9E-05

exposure is greater than one. Further evaluation shows that the majority of the risk is due to manganese. For future workers, exposure to contaminants in groundwater may occur via three routes: ingestion, dermal contact, and inhalation. The risk associated with exposure to the upper shallow, lower shallow, and deep aquifer was estimated. Contaminant specific excess cancer risks and hazard indices for the pathways are presented in Appendix D, Tables D-23 through D-28 and D-33 through D-50, and Table 5-2. The future risk for exposure to groundwater was evaluated for each aquifer separately, with the assumption that only one aquifer would be used during the exposure period. For each aquifer the predicted future cancer rates for ingestion, dermal contact, and inhalation of volatiles during showering were calculated. PRC did not include the risks calculated for the inhalation on metals during showering. Metals are not expected to volatilize during showering therefore making this exposure incomplete. For the upper shallow aquifer the total risk was  $1\text{E-}03$ , which is outside EPA's acceptable risk range, with a major portion of the risk attributed to 1,2-DCA, 1,1-DCE, vinyl chloride, chloroform, carbon tetrachloride, and tetrachloroethene. The noncarcinogenic risk for ingestion was  $1.2\text{E}+01$ , which indicate concern for potential adverse effects. Nitrate and manganese were the only two chemicals that had hazard quotients greater than 1.0. Exposure to groundwater from the lower shallow aquifer did not show any significant carcinogenic ( $3\text{E-}07$ ) or noncarcinogenic ( $\text{HQ}=4.7\text{E-}01$ ) risks. The estimated future carcinogenic risks for exposure to deep groundwater were  $4\text{E-}05$ , most of the risk was attributed to 1,2-DCA. The hazard quotient was estimated at  $8.2\text{E-}04$ , which is not a significant noncarcinogenic health threat.

### 5.3.2 Trespassers

Soil ingestion, particulate inhalation, and dermal contact pathways were considered for a potential adult trespasser on the Jayhawk site. An infrequent exposure period of 10 events per year, each 8 hours in duration, was assumed for this pathway. Sample results from site Areas A, B, and C and subsurface combined were used to determine risks to a trespasser. On-site particulate air emissions were predicted using the Cowherd (1985) model (see Appendix C).

The cancer risk predicted for soil ingestion, dermal contact, and inhalation of particulates were estimated to be  $1\text{E-}05$ , with a major portion of the risk attributed to dioxins, PCBs, and BAP. The hazard quotient for ingestion, dermal contact, or inhalation of fugitive dusts did not exceed  $3.4\text{E-}02$ , which is not a significant noncarcinogenic health threat.

TABLE 5-2

## SUMMARIES OF EXCESS CANCER RISKS AND HAZARD INDICES

## Future Land Use Conditions -- Occupational Exposure

Medium	Exposure Pathway	Excess Cancer Risks	Hazard Indices
Surface Soils Areas A, B, and C+ subsurface soils	Incidental Ingestion	4E-05	7.0E-02
	Dermal Contact	3E-04	5.1E-01
	Inhalation of Fugitive Dust	3E-05	9.5E-01
	TOTAL	4E-04	1.5E+00
Upper Shallow Groundwater	Ingestion	9E-04	1.2E+01
	Dermal Contact	2E-04	8.4E-01
	Inhalation-Showers	8E-04	1.9E-01
	TOTAL	1E-03	2.2E+00
Lower Shallow Groundwater	Ingestion	2E-07	4.7E-01
	Dermal Contact	3E-08	3.7E-03
	Inhalation-Showers	2E-08	2.0E-04
	TOTAL	3E-07	4.7E-01
Deep Groundwater	Ingestion	2E-05	7.4E-04
	Dermal Contact	5E-07	1.9E-05
	Inhalation - Showers	2E-05	6.0E-05
	TOTAL	4E-05	8.2E-04

Chemical-specific excess cancer risks and hazard indices for the trespasser pathway are presented in Appendix D, Tables D-51 through D-56, and are summarized in Table 5-3.

#### **5.4 COMBINED PATHWAY CANCER RISKS AND HAZARD INDICES**

Risks for specific exposure pathways are combined to determine potential total excess cancer risks and hazard indices for receptor populations. Specific receptors and the pathways to which they are potentially exposed are described in the following sections and summarized in Tables 5-4, 5-5, 5-6, and 5-7. Receptors include current and future workers and trespassers.

##### **5.4.1 Occupational Scenario**

This receptor is potentially exposed to contaminated soils and groundwater. Soil exposure is part of routine operations in the various areas at the site, and exposure to groundwater currently occurs through showering. This assessment also assumed that the worker would be exposed through ingestion of groundwater as a future exposure scenario, although this is not occurring at this time. Current occupational scenarios were combined only for each individual area of surface soil. Each area was combined with exposures with deep groundwater by inhalation and dermal contact for current employees. Future occupational exposures were combined by summing risks for exposure to surface and subsurface soil from the entire site with groundwater ingestion, dermal contact, and inhalation of volatiles during showering from each aquifer separately.

For current occupational exposure, the combined excess cancer risk for exposure to soils in Area A and groundwater from the deep aquifer is  $1\text{E-}04$ , with most of the risk being contributed by PCDD, PCBs, BAP, and 1,2-DCA. The combined HI for Area A and deep groundwater is  $2.6\text{E-}02$ , which is not significant.

The combined excess cancer risk for current occupational exposure to Area B and groundwater from the deep aquifer is  $3\text{E-}05$ , with most of the risk being contributed by PCBs, BAP, and 1,2-DCA. The HI for Area B and deep groundwater is  $4.8\text{E-}01$ , which is not significant.

TABLE 5-3

## SUMMARIES OF EXCESS CANCER RISKS AND HAZARD INDICES

## Future Land Use Conditions - Trespasser

Medium	Exposure Pathway	Excess Cancer Risks	Hazard Indices
		Adult	Adult
Surface Soils - Areas A, B, and C	Incidental Ingestion	3E-06	5.4E-03
	Dermal Contact	6E-06	9.8E-03
	Inhalation of Fugitive Dust	6E-07	1.9E-02
	TOTAL	1E-05	3.4E-02

TABLE 5-4

**SUMMARIES OF EXCESS CANCER RISKS**  
Current Exposure

Exposure Pathway	Occupational			
	Area A	Area B	Area C	Subsurface
Soil Ingestion	1E-05	5E-07	2E-06	4E-08
Soil Dermal Contact	1E-04	5E-06	8E-06	6E-07
Soil Inhalation Particulate	1E-07	7E-09	6E-06	NA
Groundwater Dermal Contact - Deep	5E-07	5E-07	5E-07	5E-07
Groundwater Inhalation of Volatiles While Showering - Deep	2E-05	2E-05	2E-05	2E-05
<b>TOTAL EXCESS CANCER RISK</b>	1E-04	3E-05	4E-05	2E-05

Note:

<sup>a</sup> The total risk was calculated using the groundwater zone exhibiting the highest risk.



TABLE 5-5

**SUMMARIES OF HAZARD INDICES**  
**Current Exposure**

Exposure Pathway	Occupational			
	Area A	Area B	Area C	Subsurface
Soil Ingestion	8.5E-03	6.4E-03	1.5E-02	3.6E-03
Soil Dermal Contact	1.7E-02	1.4E-01	9.5E-02	1.1E-02
Soil Inhalation Particulate	6.7E-04	3.3E-01	1.1E-01	NA
Groundwater Dermal Contact - Deep	1.9E-05	1.9E-05	1.9E-05	1.9E-05
Groundwater Inhalation of Volatiles While Showering - Deep	6.0E-05	6.0E-05	6.0E-05	6.0E-05
<b>TOTAL HAZARD INDICES</b>	2.6E-02	4.8E-01	2.2E-01	1.5E-02

TABLE 5-6

SUMMARIES OF EXCESS CANCER RISKS  
Future Exposure

Exposure Pathway	Occupational				Trespasser
	Upper Shallow Aquifer	Lower Shallow Aquifer	Deep Aquifer		
Groundwater Ingestion	4E-04	2E-07	2E-05		NA
Groundwater Dermal Contact	2E-04	3E-08	5E-07		NA
Groundwater-Inhalation of Volatiles While Showering	8E-04	2E-08	2E-05		NA
Soil Ingestion	4E-05	4E-05	4E-05		3E-06
Soil Dermal Contact	3E-04	3E-04	3E-04		6E-06
Soil Inhalation of Dust	3E-05	3E-05	3E-05		6E-07
TOTAL EXCESS CANCER RISK	2E-03	4E-04	4E-04		1E-05

TABLE 5-7

SUMMARIES OF HAZARD INDICES  
Future Exposure

Exposure Pathway	Occupational			Trespasser
	Upper Shallow Aquifer	Lower Shallow Aquifer	Deep Aquifer	
Groundwater Ingestion	1.2E+01	4.7E-01	7.4E-04	NA
Groundwater Dermal Contact	8.4E-01	3.7E-03	1.9E-05	NA
Groundwater-Inhalation of Volatiles While Showering	1.9E-01	2.0E-04	6.0E-05	NA
Soil-Ingestion	7.0E-02	7.0E-02	7.0E-02	5.4E-03
Soil-Dermal Contact	5.1E-01	5.1E-01	5.1E-01	9.8E-03
Soil-Inhalation of Dust	9.5E-01	9.5E-01	9.5E-01	1.9E-02
TOTAL HAZARD INDICES	1.5E+01	2.0E+00	1.5E+00	5.0E-02

For exposure to Area C soils and groundwater from the deep aquifer, the combined excess cancer risk is  $4\text{E-}05$ , with most of the risk being contributed by arsenic, PCBs, methylene chloride, and 1,2-DCA. The combined HI for Area C and deep groundwater is  $2.2\text{E-}01$ , which is not significant.

As stated earlier, the future occupational exposure scenario included exposure to soils from all three areas and the subsurface and exposure to groundwater. When summing the risks for the future occupational exposure, it was assumed that exposure would occur site-wide to soils and groundwater from one aquifer: upper shallow, lower shallow, or deep aquifer. Therefore, three different risk summations were calculated.

For the future occupational exposure to site-wide soils and the upper shallow aquifer, the combined excess cancer risk is  $2\text{E-}03$ . The major portion of the risk is associated with the following: 1,2-DCA, 1,1-DCE, vinyl chloride, chloroform, carbon tetrachloride, and tetrachlorethane in groundwater, and PCDD, 2,3,7,8-TCDD, PCBs, BAP, and chromium in soils. The combined HIs for site-wide soils and the upper shallow aquifer is  $1.5\text{E+}01$ , which is significant. Nitrate and manganese were the two chemicals that had HIs above unity in the groundwater.

The combined excess cancer risk for future occupational exposure to site-wide soils and the lower shallow aquifer is  $4\text{E-}04$ . The majority of the risk is associated with the exposure to soils and the chemicals are PCDD, 2,3,7,3-TCDD, PCBs, BAP, and chromium. The combined HIs for site-wide soils and the lower shallow aquifer is  $2.0\text{E+}00$ , which may be significant. However, no one chemical's hazard quotient exceeded unity. Manganese is the one chemical that contributes most to the risk for soil dermal contact and inhalation of dust; the combination of these HIs from two pathways exceed unity and indicates a potential risk. In the remaining exposures, the predominant chemicals, cadmium and zinc, do not effect the same target organ. Therefore, they should not be added, and do not indicate a risk.

For exposure to site-wide soils and groundwater from the deep aquifer, the combined excess cancer risk is  $4\text{E-}04$ . The majority of the risk is associated with soils and the chemicals were identified above. The combined HIs for site-wide soils and the deep aquifer is  $1.5\text{E+}00$ , which may be significant. Although no chemical's hazard quotient exceeded unity, manganese was the major

chemical for the HI, and the combined HIs from soil contact and inhalation of dust exceed unity, and this indicates a potential risk.

#### **5.4.2 Trespasser Scenario**

The trespasser receptor is assumed to be infrequently exposed to on-site contaminants. This receptor is hypothetically an area resident who enters the site for a 8-hour period up to 10 times a year. Soil ingestion and dermal contact exposure are assumed, as well as inhalation of dust from the soil. The combined cancer risks and hazard indices for this receptor total  $1\text{E-}05$  and  $5.0\text{E-}02$ , respectively.

### **5.5 QUALITATIVE RISK ASSESSMENT**

Many chemicals were identified at the Jayhawk site that did not have risk factors associated with them. Without these risk factors, risks associated with these chemicals could not be quantified. Chemicals without quantifiable risk factors are discussed qualitatively in the sections below. Of these chemicals, lead represented the only probable significant risk.

#### **5.5.1 Chemicals Without Toxicity Values**

Risks associated with certain contaminants detected at the site were not quantified because risk factors were not available. These contaminants include chemicals that have been confirmed as present on the site based on qualified data. Compounds confirmed as present in site-related media are listed in Appendix D along with the contaminants for which quantitative risks were assessed. The percentage of chemicals in each pathway that do not have toxicity values (that is, both cancer slope factors and RFDs) were reviewed. For the soil pathways, approximately 20 percent of the detected contaminants do not have toxicity values. For the inhalation pathways, up to 50 percent of the detected contaminants do not have toxicity values. For the groundwater pathways, up to 20 percent of the detected contaminants do not have toxicity values. For compounds without toxicity values, the actual risks may be equal to or less than the risks calculated using known toxicity values. Most compounds with a high frequency of detection had toxicity values ensuring that most of the risk associated with the site was estimated.

### **5.5.2 Exposure to Lead**

This section presents a qualitative evaluation of lead toxicity. Lead is included because of high lead levels detected and because of well documented health problems associated with lead exposure. The risk of health effects related to lead exposure varies according to the individual, depending on nutritional status, age, and total lead body burden from all sources. Children are considered the most sensitive population. Women are generally more sensitive than men to the effects of lead in the blood system. Also, fetuses may be at particular risk.

There may be no threshold for the adverse effects of lead, particularly for neurobehavioral effects in children. A concentration of lead as low as 1 mg/L in drinking water has been demonstrated to produce clinical lead poisoning (NLM 1990). However, no RME lead concentrations greater than 2 µg/L were estimated for groundwater at the site based on RI, Weston-Allcon and Allied Signal sampling.

Lead also has been measured in surface and subsurface soils at the site. In particular, the RME lead concentrations are 887, 107, 197, and 182 parts per million for surface soil in Area A, Area B, Area C, and subsurface soils respectively. The maximum lead concentration observed was 5,390 mg/kg in Area A.

The Center for Disease Control (CDC 1985) has published guidance for lead concentrations in residential soils that the CDC associates with an acceptable level of risk. Specifically, CDC personnel concluded that adverse clinical and health effects (elevated blood lead levels) may result from exposure to lead levels in soils and dust at concentrations exceeding 500 to 1,000 mg/kg. Exposure to soils with lead concentrations less than 1,000 mg/kg is generally not expected to result in adverse health effects in industrial exposures. The data from the site indicates that there are locations on the facility that exceed the guidance levels and the RME levels for Area A approach those levels.

### **5.6 UNCERTAINTIES IN RISK CHARACTERIZATION**

Risk estimates calculated in this risk assessment are subject to varying degrees of uncertainty from a variety of sources. In contrast to the uncertainties involved in estimating exposure, the uncertainties

inherent in risk characterization depend less on availability of site-specific information and more on availability and use of chemical-specific toxicity information. This section identifies the most significant sources of uncertainty for the risk characterization and assesses the potential impact of the uncertainty.

The following sources of uncertainty are discussed:

- Risk factors
  - Extrapolations (related to species, exposure dose, and exposure period)
  - Adjustment of risk factors
  - Slope factors
  - Lack of risk factors
- Risk summations
- Chemicals of concern
- Exposure periods

Table 5-8 summarizes these sources of uncertainty and expresses the likely effect of each uncertainty on the estimated risks by indicating whether the effect of the uncertainty will be to (1) overestimate the risk, (2) underestimate the risk, or (3) overestimate or underestimate the risk.

#### **5.6.1 Risk Factors**

Risk factors, such as slope factors and RfDs, are used to characterize risks associated with estimated exposures. However, uncertainty is involved in development and use of risk factors. Four specific sources of uncertainty are discussed below.

##### **5.6.1.1 Extrapolations**

Risk factors (slope factors and RfDs) used in evaluating human health risks were developed using extrapolations made for species, exposure dose, and exposure period. These are discussed below

TABLE 5-8  
AREAS OF UNCERTAINTY AND EFFECTS ON RISK ESTIMATES

Area of Uncertainty		May Overestimate Exposure	May Underestimate Exposure	May Overestimate or Underestimate Exposure
<b>Risk Factors</b>				
• Extrapolation		X		
Most risk factors are extrapolated from animal test results. Extrapolations, which may be made for species, exposure dose, and exposure period, are generally conservative.				
• Adjustment of Oral Risk Factors			X	
In order to characterize risks from dermal exposures, generally expressed as absorbed doses, EPA (1989b) recommends that oral risk factors be adjusted to account for oral absorption efficiency. These adjustments were not made.				
• Slope Factors (SF)		X		
Slope factors represent upper 95 percent confidence limit values; carcinogenic risks calculated using slope factors generally represent upper-bound estimates.				
• Lack of Risk Factors			X	
Risks from exposure to chemicals with no available chemical-specific or substitute risk factors cannot be quantitatively characterized.				
<b>Risk Summations</b>				
• Risks from chemical mixtures are characterized by summing the individual chemical risks. This procedure assumes that chemicals have the same toxic end points and mechanisms of action and do not interact either synergistically or antagonistically. These assumptions may be incorrect.				X
<b>Chemicals of Concern</b>				
• Risks were calculated for all chemicals that were found in at least one sample. This assumes that all chemicals found at the site are due to site activities, this is a conservative assumption.		X		
<b>Exposure Periods</b>				
• Subchronic exposures are characterized by comparison to chronic risk factors if subchronic factors are not available. Evaluating exposures using risk factors based on longer exposure is conservative.		X		
• Exposures predicted during which receptors can be expected to produce and sustain an equilibrium concentration are likely to be conservative.		X		



Most risk factors were based on animal test results. However, humans may differ from test animals in uptake, metabolism, distribution, and elimination of chemicals. Risk factors are generally developed under the assumption that a human is as sensitive to a chemical as the test animal, even though results for the most sensitive test species are generally used as the basis for the risk factors. An uncertainty factor (usually 10, but sometimes up to 1,000) is incorporated into the risk factor to account for any greater human sensitivity. To the extent that human beings are more or less sensitive than the test animals, results may underestimate or (more likely) overestimate the true risks to humans.

In the laboratory, test animals are usually exposed regularly for less than 2 years to high chemical doses. In contrast, humans are likely to be exposed to much lower chemical doses on a less regular basis for widely varying exposure periods. Limited human data exist for many chemicals characterized as carcinogenic in this risk assessment. Most of the evidence used to characterize these chemicals as carcinogenic is from animal studies. To the extent that particular chemicals are ultimately shown *not* to be carcinogenic to humans, carcinogenic risks presented in this risk assessment may overestimate actual carcinogenic risks associated with the site.

However, many noncarcinogenic health effects may have thresholds, meaning that they are not observed under low-dose or infrequent exposure conditions. If actual human exposures are below chemical-specific thresholds, use of risk factors based on laboratory exposures may result in an overestimation of actual risks.

In general, risk factors are very conservative to protect human health. In the risk characterization, therefore, estimated risks may overestimate true risks.

#### **5.6.1.2 Adjustment of Risk Factors**

This risk assessment presents carcinogenic and noncarcinogenic risks for chemicals with available risk factors (RfDs and slope factors). Most available risk factors were derived from experiments in which the route of exposure was ingestion. The resulting oral risk factors are related to the amount of substance administered per unit of time and unit of body weight. When dermal routes of exposure are considered, exposures are expressed as absorbed rather than administered doses. To estimate

risks for dermal routes of exposure, it is recommended that risk factors also be expressed in terms of absorbed doses. As noted in Section 5.1.2, for this risk assessment the risk factors were not adjusted. Therefore, the exposure may have been underestimated.

However, estimating risks from dermal exposure involves making several additional assumptions that do not apply to risks from oral exposure. Therefore, the uncertainty associated with estimating dermal risks is greater. Because of the high degree of uncertainty involved in estimating risks from dermal exposure to chemicals and because of the conservative nature of the assumptions involved, risks estimated for dermal exposures are more likely to overestimate actual risks than estimations made for other exposure pathways.

#### **5.6.1.3 Slope Factors**

Slope factors represent the upper 95-percent confidence limit values, based on the linearized, multistage carcinogenesis model. The estimated carcinogenic risks calculated using slope factors generally represent upper bound estimates of the true risks. Therefore, the use of these slope factors may have resulted in an overestimation of the true risks at the Jayhawk site. Specifically, true risks are unlikely to be greater than the estimated values, and are likely to be less.

#### **5.6.1.4 Lack of Risk Factors**

Uncertainty was introduced by the lack of risk factors for some chemicals for which appropriate substitutes are not available. In not evaluating the risks from potential exposures to these chemicals, true risks may have been underestimated. The percentages of chemicals for which toxicity values were not available are noted in Section 5.5. Risks are potentially underestimated by these percentages if the assumption is made that the compounds without toxicity values present risks that are comparable to those contaminants that have toxicity values.

#### **5.6.2 Risk Summations**

Risks from chemical mixtures found at the Jayhawk site were calculated by summing individual chemical risks. This procedure is recommended by EPA guidance (1986 and 1989a) and assumes that

all chemicals have the same toxic endpoints and mechanisms of action. However, this assumption may be incorrect; the chemicals may, in fact, have different toxic endpoints and mechanisms of action. Furthermore, chemicals in a mixture at the Jayhawk site may act synergistically or antagonistically once they enter the human body. Little information is currently available on synergistic or antagonistic actions within chemical mixtures. Interactions between chemicals in a mixture may form new toxic components or may cause changes in the bioavailability of the existing chemicals. Summation of individual chemical risks within and across exposure pathways, therefore, may have overestimated or underestimated true risks.

#### **5.6.3 Chemicals of Concern**

The Baseline Risk Assessment evaluated all chemicals detected at least once in groundwater or soil. Several chemicals, as shown in Appendix A, exhibited a low frequency of detection (e.g., five percent or less based on a minimum of 20 samples for a given medium). Inclusion of chemicals detected at a frequency of five percent or less may lead to an overestimate of risk as the presence of these chemicals may be the result of artifacts in the data due to sampling, analytical, or other problems. Chemicals detected at a frequency of five percent or less may not be related to site operations or disposal practices.

For the Jayhawk Site risk assessment, at least one compound (PCDD, detected once out of 44 samples) detected at a frequency of five percent or less contributed greater than 50 percent of the risk. Inclusion of this compound and the associated risk may result in an overestimate of the risk from exposure to soil in the vicinity of Group A. Eliminating PCDD based on frequency of detection reduces the risk from soil exposure through dermal contact and ingestion by approximately one order of magnitude (reduced to  $10^{-5}$  from  $10^{-4}$ )."

#### **5.6.4 Exposure Periods**

Exposure periods over which exposure doses were calculated should be similar to exposure periods for risk factors used to assess risks associated with the exposure doses. For example, chronic exposure doses should be evaluated using chronic risk factors. For this risk assessment, subchronic exposure doses were evaluated using chronic risk factors when subchronic risks factors were not

available. In addition, because of the lack of appropriate test data, subchronic RfDs for some chemicals were the same as their chronic RfDs. Evaluating exposure doses using risk factors based on longer exposure periods is conservative and generally results in an overestimation of true risks.

Exposure periods for inhalation of predicted airborne contaminants were assumed to be 25 years for workers. As previously noted, the air dispersion models were conservative and may overestimate contaminant concentrations in air. In addition, the period of time over which the predicted contaminant concentrations can be present in the ambient air is limited by the mass of the contaminants present in on-site soils. This period is likely to be significantly less than 25 years. As such, the risks determined for the ambient air inhalation pathways are likely to have been overestimated.

## CHAPTER 6

### ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment was conducted at the Jayhawk site. The ecological risk assessment was conducted based on guidance contained in EPA (1989b). The following five sections detail the ecological risk assessment.

#### 6.1 INTRODUCTION

This ecological risk assessment is part of a baseline risk assessment designed to assess the potential human health and environmental impacts associated with the Jayhawk site. According to EPA (1991b) an ecological assessment consists of four main sections:

Problem Formulation: This includes a description of ecological receptors and habitats potentially affected by site-related contamination, selection and characterization of contaminants of ecological concern, and description of exposure pathways.

Exposure Assessment: This includes quantification of contaminant release, fate and transport, measurement and estimation of exposure point concentrations; and characterization of selected receptors.

Ecological Effects Assessment: This includes toxicological effects assessment based on published toxicity benchmarks for terrestrial and aquatic receptors.

Effect Characterization: This includes a qualitative description of the potential adverse impacts on ecological receptors based on information described in the previous sections.

##### 6.1.1 Objective of the Assessment

The objective of this assessment is to determine if metals and volatile and semivolatile compounds released on the site will have an adverse ecological effect on terrestrial and aquatic habitats on the Jayhawk site and in the vicinity.

### **6.1.2 Scope of the Investigation**

The site's media were sampled as part of KDHE remedial activities from 1989 to 1992. Investigations have provided physical and chemical data on groundwater, surface water, sediment, surface soil, and subsurface soil. No ecological data have been gathered for the site thus far.

This ecological assessment will describe potential ecological impacts to likely ecological receptors by relating site-derived chemical data, such as exposure point concentrations, to ecological receptors via exposure pathways. Because no on-site ecological survey data are available, other published information will be used.

### **6.1.3 Site Characterization**

A walk-through inspection of the site in early 1993 indicated that the undeveloped portions of the site consist of farm pasture-land vegetated with grass. No other special ecological systems were noted on site.

## **6.2 ECOLOGICAL RECEPTORS**

Information on receptors that may come in contact with site-related contaminants is derived from a list of state-listed threatened and endangered species in Cherokee County, Kansas, provided by the Kansas Department of Wildlife and Parks (KDWP) (KDHE 1990).

The following sections provide details on the ecological receptors at the Jayhawk site:

- Potentially affected species
- Potentially affected habitats
- Contaminants of ecological concern
- Exposure pathways

### 6.2.1 Potentially Affected Species

Several species listed as threatened and endangered in the state of Kansas have been reported by KDWP as occurring in the vicinity of the site. Each species, its status, its occurrence in Cherokee County, and the designation of critical habitat in Cherokee County is presented in Table 6-1.

### 6.2.2 Potentially Affected Habitats

Based on sampling data, modeling efforts, and the history of contaminant release at the site, potentially affected habitats include:

- The grounds of the site
- Shawnee Creek to the west of the site
- Spring River
- The intermittent stream to the south of the site

### 6.2.3 Contaminants of Ecological Concern

Contaminants of ecological concern are substances that are likely to cause adverse effects on ecological receptors. The overall approach to selecting contaminants of ecological concern usually includes the following steps:

- Evaluation of the physical and chemical properties of detected contaminants to predict their fate and transport in the environment
- Evaluation of the toxicity of detected contaminants to ecological receptors
- Analysis of frequency of detection of the contaminants in environmental media
- Comparison of detected contaminant concentrations with site background data

The scope of this ecological assessment did not allow for an extensive screening process to select contaminants of ecological concern with a low degree of uncertainty. Instead, the selection of COPCs focused on contaminants that had very high concentrations in soil or

TABLE 6-1

## THREATENED AND ENDANGERED SPECIES OCCURRING IN THE STATE OF KANSAS

Species	Status	Local Occurrence	Critical Habitat
Arkansas Darter	T	Occurs in Spring River Tributaries	Yes
Bald Eagle	E	Occurs occasionally in winter	No
Broadhead Skunk	T	Occurs in suitable habitat	No
Cave Salamander	E	Occurs in suitable habitat	Yes
Central Newt	T	Occurs in suitable habitat	Yes
Dark-sided Salamander	T	Occurs in suitable habitat	Yes
E. Hognose Snake	T	May occur in suitable habitat	No
E. Narrowmouth Toad	T	Occurs in suitable habitat	Yes
E. Spotted Skunk	T	May occur in suitable habitat	No
Gray Myotis	E	May occur in suitable habitat	Yes
Graybelly Salamander	E	Occurs in suitable habitat	Yes
Green Frog	T	Occurs in suitable habitat	Yes
Groto Salamander	E	Occurs in suitable habitat	Yes
Heel-splitter Mussel	E	May occur in suitable habitat	No
Least Tern	E	May occur occasionally in summer	No
Neosho Madtom	T	Occurs in Neosho and Spring Rivers	Yes
N. Crawfish Frog	T	Occurs in suitable habitat	Yes
N. Redbelly Snake	T	May occur in suitable habitat	No
N. Spring Peeper	T	Occurs in suitable habitat	Yes
Peregrine Falcon	E	May occur occasionally in winter	No
Piping Plover	T	May occur occasionally, spring and fall	Yes
Redspot Chub	T	Occurs in Spring River tributaries	Yes
Snowy Plover	T	May occur occasionally, spring and summer	No
White-faced Ibis	T	May occur occasionally, spring through fall	No

Notes:

T      Threatened  
E      Endangered



groundwater sampling. The list is not identical to the list of contaminants of potential concern for human health because of different chemical specific sensitivities.

For the purpose of this ecological risk assessment, a concentration of three times background concentrations was considered significant. Chemicals detected in soil significantly above background concentrations, and considered contaminants of potential concern for the ecological pathway are the same as those given in Tables 2-1 and 2-2.

#### 6.2.4 Exposure Pathways

The objective of the exposure pathway evaluation is to select the most likely exposure pathways by which organisms present at the site may contact site chemicals and the most important factors influencing these exposures. By identifying the most likely exposure pathways, an evaluation of potential environmental impacts can be limited to those pathways that are expected to comprise the majority of effects to ecological receptors. Factors which influence exposures of ecological receptors to site chemicals are:

- Site-specific geological, physical, and chemical conditions
- Seasonal and climatic variations
- Exposure point concentrations
- Duration of expected exposure
- Frequency of exposure

The pathways by which aquatic receptors may be exposed to site chemicals are:

- Exposure of benthic and epibenthic invertebrates, and benthic fish to chemicals bound to sediments
- Exposure of benthic and epibenthic invertebrates, and benthic fish to chemicals found in the water column through ingestion, dermal absorption, and respiration
- Exposure of benthic and epibenthic invertebrates to chemicals found in the interstitial water of the sediments through ingestion, dermal absorption, and respiration

Sampling data are available from the surface water column and from the solid portion of the sediments in the ditch. Therefore, aquatic pathways to be evaluated will include exposure to surface water and solid-phase sediments.

Exposure of terrestrial organisms to chemicals can occur through the following pathways;

- Direct ingestion of chemicals from groundwater seeps and springs
- Direct ingestion of chemicals in surface water
- Direct ingestion of chemicals in soil
- Indirect ingestion of chemicals in contaminated plants and prey
- Plant root uptake of chemicals in soil
- Direct dermal absorption of chemicals from surface water
- Direct dermal absorption of chemicals from soil
- Direct inhalation of chemicals volatilizing from groundwater
- Direct inhalation of chemicals volatilizing from surface water
- Direct inhalation of chemicals volatilizing from soil

Direct ingestion of chemicals from groundwater seeps and springs will not be considered in the assessment because the presence of groundwater seeps and springs has not been confirmed.

Direct ingestion of chemicals from surface water is a likely pathway, due to the need of all terrestrial receptors for fresh water and its availability in Shawnee Creek, the intermittent stream, and the Spring River.

Terrestrial species that feed on decaying organic material in soil or burrow through soil may directly ingest soils. This exposure pathway is the most likely for such terrestrial species, and is less likely for nonburrowing mammals and birds since soil ingestion is mainly incidental.

Indirect ingestion of chemicals through contaminated plants and prey is a likely pathway for both carnivorous and herbivorous species. Plants are known for their potential to bioconcentrate organics (Travis and Arms 1988). Carnivorous species can be subject to elevated levels of chemicals from bioaccumulation and biomagnification through the food chain.

Direct dermal absorption of chemicals from groundwater is unlikely since no groundwater seeps or springs have been observed at the site.

Direct dermal absorption of chemicals from surface water is a likely pathway for species which spend some time in stagnant water, such as raccoon, river otter, and waterfowl.

Direct dermal absorption of chemicals from soil may be a pathway for those species that live in continuous contact with soils, such as burrowing mammals and subterranean insects. However, fur and feathers on these species help prevent direct dermal contact with chemicals in soil and reduce absorption through such contact.

The exposure pathways that are based on the inhalation route are not considered significant for exposure by ecological receptors because the contribution to total exposure from dietary exposure and contact with soil are expected to be greater than contributions from inhalation.

In summary, the highest exposure potential is associated with the following pathways:

- Direct dermal absorption of contaminants in soil
- Direct uptake of contaminants through plant roots
- Indirect ingestion of constituents of potential concern in contaminated food

## **6.3 EXPOSURE ASSESSMENT**

The exposure assessment consists of quantification of release, fate, and transport, and exposure point concentrations. The following two sections discuss these areas.

### **6.3.1 Quantification of Release, Fate, and Transport**

Environmental media sampling data show that contaminants have been released to soil and groundwater. Sampling data from groundwater wells indicate that three plumes may exist, one carrying 1,2-DCA and two carrying xylenes.

### **6.3.2 Exposure Point Concentrations**

Soil contamination data from on-site sampling locations represent exposure point concentrations. Although results indicate that groundwater contamination is not reaching the Spring River, concentrations of contaminants measured in groundwater can be regarded as maximum exposure point concentrations should contaminants reach the river in the future.

### **6.3.3 Characterization of Receptors**

Habitats associated with the Jayhawk site host a large number of species, populations, and communities. Exposure assessments usually select a small number of receptors that serve as indicator species for the remaining biota. These receptors are supposed to be representative in terms of sensitivity, habitat requirements, and taxonomic spectrum. The indicator species are also selected on the basis of available benchmark data that can be used as endpoints in an assessment, such as NOAEL, lowest observable adverse effect level (LOAEL), LC50, and lethal dose 50 percent (LD50). Receptor characterization usually focuses on terrestrial receptors since all aquatic species are sufficiently protected by available ambient water quality criteria (EPA 1991c). Because of the lack of data on receptor presence and duration of stay on the site or in potentially affected habitats, a complete characterization of terrestrial receptors cannot be made at this time. However, under a conservative scenario, the species that are described as occurring in suitable habitat and have a critical habitat designated in Cherokee County, could be assumed to frequent the site. State-listed endangered species assumed to frequent the site are the cave salamander, the graybelly salamander, and the grotto salamander. State-listed threatened species assumed to frequent the site are the central newt, the dark-sided salamander, the E. narrowmouth toad, the green frog, the N. crawfish frog, and the N. spring peeper.

## **6.4 ECOLOGICAL EFFECTS ASSESSMENT**

Both aquatic and terrestrial effects were included in the ecological risk assessment. The following two sections detail those effects.

#### 6.4.1 Aquatic Toxicity Data

Surface water sampling data collected during the RI for the site does not indicate that the site is impacting the Spring River. Therefore, based on limited sampling, surface water and sediments from Spring River are not expected to pose any risks to exposed organisms.

#### 6.4.2 Terrestrial Toxicity Data

Terrestrial toxicity data are usually based on published results of toxicity studies that have been conducted on a limited number of species in laboratories. The effects of different chemicals have been evaluated on species such as mallards, chickens, rats, white-tailed deer, dogs, rabbits, and raccoons (Patton and Dieter 1980; Eisler 1985 and 1987). Data from laboratory species that most closely resemble chosen indicator species are then modified for indicator species-specific uptake. For this purpose, the ingestion rates of the indicator species for water, plants, and prey, the duration and proportion of uptake of contaminated food sources, gastrointestinal absorption factors, and other parameters such as uncertainty need to be determined. However, there are currently no data available on confirmed presence of receptors, their duration of stay, and their ingestion ratios. In addition, the scope of this assessment did not allow for a thorough literature search on toxicity benchmarks and estimation of contaminant dosages in terrestrial receptors. Consequently, no assessment of ecological effects on ecological receptors via terrestrial exposure pathways was made.

### 6.5 RISK CHARACTERIZATION

There are no data available indicating that ecological receptors are currently experiencing adverse effects from on-site contaminants.

To address the potential for exposure of ecological receptors to site-related contamination more thoroughly, additional data need to be collected. The potential for adverse effects on terrestrial receptors exposed to uptake of contaminated soil could be described in more depth if an ecological survey of the site established the presence and duration of individual species on the site or demonstrated readily visible damage to plants or animals. Such data and a thorough literature survey

would form the basis for establishing parameters to calculate uptake dosages and allow comparisons to literature-based toxicity benchmarks.

## CHAPTER 7

### RISK ASSESSMENT SUMMARY

The Jayhawk site risk assessment is primarily based on sample data collected from the site during a previous RI and two site assessments. Surface soil, subsurface soil, groundwater, surface water, and sediment data were collected during these investigations. Contaminants detected in these media were used to characterize the nature and extent of the human and ecological risks posed by the site. The following sections highlight the chemicals of potential concern detected on and around the site, significant exposure pathways associated with the site area, and the significant risks to human and ecological receptors. Sections 7.1 through 7.4 address the components of the human health risk assessment. Section 7.5 summarizes the major issues associated with the ecological assessment of the site.

#### 7.1 CHEMICALS OF POTENTIAL CONCERN

Chemicals of potential concern found at the Jayhawk site include VOCs, semivolatile organic compounds, PCBs (Arochlor 1254), and metals. Some or all of the contaminant groups are present in on-site soils, in on-site groundwater, and in sediments and surface water. Ambient air has not been measured for contaminants; concentrations were predicted by air modeling for this assessment. All other exposure point concentrations were determined from the RI and Allico and Allied Signal site assessment data.

For this risk assessment, PRC divided the soils into four groups: (1) soils near the former Koch plant (Area A), (2) soils from the abandoned disposal area (Area B), (3) soils from the northern portion of the site (Area C), and (4) subsurface soils. Contaminants from all the above mentioned categories have been measured in all on-site soils. The area of highest contamination in soils is the area associated with the ongoing industrial activity (Area A).

Groundwater data also was segregated into three groups: (1) the upper shallow aquifer, (2) the lower shallow aquifer, and (3) the deep aquifer. The highest extent of contamination was found in the upper shallow aquifer, with VOCs and metals as the predominant contaminants. Many of the same constituents noted in the soils also were noted in the groundwater.

Surface water and sediment samples were taken during the previous investigations. However, no significant difference was noted by PRC between samples from upstream and downstream of the site.

Specific chemicals of potential concern detected in on-site soils and groundwater that pose significant health risks are discussed in Section 7.4.

## **7.2 EXPOSURE ASSESSMENT**

The exposure assessment identified receptors that are potentially exposed to contaminants. Those receptors include on-site workers and trespassers.

A large portion of the site is presently being used as an industrial facility. It was assumed that this activity may continue. It was assumed that workers will be exposed to on-site soil through routine activities that include maintenance and repair. The workers often shower at the facility at the end of their shifts. Doing so exposes them to contaminants from deep groundwater through direct contact and through inhalation of VOCs. It was also assumed that future new wells could be drilled in the upper aquifers and exposure could occur through ingestion, dermal contact, and inhalation of VOCs.

Exposure to occasional trespassers was considered in the exposure assessment. Assumptions were made that the trespasser would be exposed infrequently to contaminated soils at the site through incidental ingestion, direct contact, and inhalation of particulates.

## **7.3 TOXICITY ASSESSMENT**

Available risk factors for carcinogens and noncarcinogens are listed in Chapter 4 for the chemicals of potential concern at the site. Contaminants at the site that potentially can cause the most significant health risks are also discussed in Chapter 4. These include 1,1-DCE, 1,2-DCA, carcinogenic PAHs, methylene chloride, PCBs, TCDD, TCE, and vinyl chloride.



#### 7.4

### RISK CHARACTERIZATION

The total upper bound excess lifetime cancer risks for current occupational exposures for Areas A, B, and C are estimated to be  $1\text{E-}04$ ,  $3\text{E-}05$ , and  $4\text{E-}05$ , respectively for all exposures. Current exposures in Area A are considered significant. The most significant risk is soil dermal contact in Area A. Risk for future employees was estimated with three scenarios which assumed exposure to site-wide soil and a specific aquifer, upper shallow, lower shallow, or deep. The highest upper bound cancer risk was seen to the future worker exposed to the upper shallow aquifer and soils,  $2\text{E-}03$ . The upper bound cancer risk for the other two scenarios were dominated by the risk associated with soil exposure; both had an excess cancer risk of  $4\text{E-}04$ . The contaminants of primary concern are DCDD, PCB, TCDD, benzo(a)pyrene, and chromium. The hazard indices did not exceed 1 for any current occupational exposure pathway. The hazard index for each of the future occupational exposure scenarios exceeded 1. Nitrate was the most significant chemical in the upper shallow aquifer and manganese was the chemical that attributes most of the risk for soil dermal contact and inhalation of dust. For trespassers, the total cancer risk is estimated at  $1\text{E-}05$  and the hazard index is  $5\text{E-}02$ , which is not considered significant to human health.

#### 7.5

### ECOLOGICAL CHARACTERIZATION

Currently, there are no data available to indicate that ecological receptors are experiencing adverse effects from on-site contaminants. Based on a qualitative evaluation, the greatest ecological risk appears to be ingestion of and dermal contact with surface soils.

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## APPENDIX C

### ESTIMATION OF PARTICULATE EMISSIONS

A conservative model for estimating particulate concentrations in air is provided by Cowherd (1985). This model calculates a particulate emission factor (PEF), which is then used to convert soil concentrations to air concentrations. The following assumptions are implicit in this model:

(1) contaminant concentrations of particles suspended in air equal measured concentrations in soil; (2) particle emissions to air occur at a steady rate; (3) soil concentrations do not change over time (for example, from volatilization or chemical reaction); and (4) both the 95 percent upper confidence limit and the maximum contaminant concentration observed were provided in the soil concentration data. The lesser of these two concentrations was used to calculate concentrations in air.

The Cowherd (1985) model was used to determine an emission rate ( $E_{10}$ ), which is then used to calculate the PEF and finally the risk or hazard quotient in the manner described by the U.S. Environmental Protection Agency (EPA) (1991). Site-specific parameters and local wind conditions are used in these calculations. Once the PEF is obtained, it is used to convert soil concentrations to air concentrations. These concentrations are used in the standard risk equations.

The method for calculating  $E_{10}$  is fairly detailed, and several assumptions and estimates are required. Reasonably conservative assumptions and estimates were used, as described in Cowherd (1985). The primary assumptions are that the site is dry and exposed to wind. Cowherd (1985) states clearly that this method should be used to provide an order-of-magnitude estimate of risk. With site-specific information, one would expect an estimate of risk using this method to be within an order of magnitude. Unfortunately, site-specific information is not readily available for this site; estimates will be used.

The first estimate is to obtain the aggregate size distribution mode of the surface soil. Ideally, the soil should be tested; however, a rough estimate may be made based on the type of soil present. The surface soils described are Dennis-Bates-Parsons silty loams; these soils tend to be both silty and loamy. The size range of silts is 0.004 to 0.063 millimeters (mm) (Driscoll 1986); silts present the greater risk of suspension. Clays present a smaller grain size but tend to form crusts, which tend not

to erode and hence present less risk. Cowherd (1985) presents a graph that relates grain size to threshold friction velocity ( $U_{*th}$ ) although the lowest aggregate size distribution mode presented is 500  $\mu m$ . By extrapolating from this graph,  $U_{*th}$  is estimated to be 50 cm/sec.

The second estimate regards the roughness height ( $Z_o$ ). The roughness height describes the local terrain, such as the roughness of the ground and the presence or absence of local buildings. Increasing this factor will increase air turbulence at the site, which has the net effect of decreasing the threshold friction velocity as measured at 7 meters ( $U_{7m}$ ). This is the typical weather station sensor height. A loose, exposed soil, such as may be found in a plowed field, is hypothesized for this site. The roughness height is estimated as approximately 1 centimeter.

The  $U_{*th}$ ,  $Z_o$ , and  $U_{7m}$  are related to each other as shown by Equation C-1.

$$U_{7m} = 2.5 \times U_{*th} \times \ln (700 \text{ cm}/Z_o) \quad (C-1)$$

where

$Z_o$	=	roughness height (cm) = 1
$U_{7m}$	=	threshold windspeed at 7 meters (m/sec)
$U_{*th}$	=	threshold friction velocity (m/sec) = 0.5 m/sec
$\ln$	=	natural logarithm function

Using Equation C-1,  $U_{7m}$  is calculated as 8.2 meters per second (m/sec).

The third estimate regards the degree to which the site is vegetated. The fraction of vegetative cover ( $V$ ) is estimated, and used directly in the equation to calculate  $E_{10}$ . The greater the degree of vegetation, the less the opportunity for particles to suspend in air. This fraction ranges from 0 to 1.0;  $V$  is conservatively estimated as 0.9 for the more heavily vegetated unexcavated portion and as 0.1 for the less vegetated excavated portion. PRC assumed 0.75 for the overall site.

Finally, Equation C-2 shows the method by which  $E_{10}$  is calculated. This equation assumes that the soil has an unlimited erosion potential. An unlimited erosion potential implies that there is little tendency to form crusts on the surface, which would limit erosion. Silty soil will exhibit some of this

characteristic, the degree is unknown. Therefore, the equation for  $E_{10}$  describing unlimited erosion potential is used.

$$E_{10} = 0.036 * (1 - V) * ([u] / U_{7m})^3 * F(x) \quad (C-2)$$

where

- $E_{10}$  =  $PM_{10}$  emission rate ( $g/m^2$ -hr); ( $PM_{10}$  represents the soil fraction with diameter less than or equal to 10 microns.)
- $V$  = fraction of vegetative cover (unitless) = 0.75
- $[u]$  = mean annual windspeed [4.9 m/sec for Galena (USDA 1985)]
- $U_{7m}$  = threshold windspeed at 7 meters (calculated earlier as 8.2 m/s)
- $F(x)$  = function plotted by Cowherd (1985) = 0.92

Using Equation C-2 with the assumptions provided above,  $x$  is calculated as 1.49 and  $F(x)$  is estimated as 0.92, according to Cowherd (1985). Finally  $E_{10}$  is calculated as  $0.005 g/m^2$ -hr for the site.

The PEF is then calculated from  $E_{10}$  using EPA guidance (EPA 1991). The PEF is used in the risk calculation and assumes a box model. This model assumes a steady emission rate from the soil into the box, a steady flow of clean air into one side of the box, and a steady exit flow of air out the opposite end of the box. A mass balance is then used to calculate the concentration in the box. This is a conservative model.

The EPA guidance considers the size of the site, the diffusion height, and the windspeed in the mixing zone (EPA 1991). The windspeed in the mixing zone is assumed equal to the mean annual windspeed of 8.2 m/sec, and the default value for the diffusion height is used. The size of the site is measured from the map provided. Equation C-3 shows the formula for calculating PEF:

$$PEF = \frac{LS \times V \times DH \times 3,600 \text{ sec/hr} \times 1,000 \text{ g/kg}}{A \times E_{10}} \quad (C-3)$$

where

- PEF = particulate emission factor ( $m^3/kg$ )



LS	=	width of the contaminated area (m)
V	=	mean annual windspeed (m/s)
DH	=	diffusion height (conservatively estimated as 2 m)
A	=	contaminated area (m <sup>2</sup> )
E <sub>10</sub>	=	emission rates (calculated in Equation C-2)

For the Jayhawk site, PRC estimated that LS is 122 m and A is 14,640 m<sup>2</sup>. Therefore, PEF is  $5.9 \times 10^7$  m<sup>3</sup>/kg.

PEF is used in standard risk equations. By dividing the soil concentration (mg/kg) for a given compound by the PEF (m<sup>3</sup>/kg), an air concentration (mg/m<sup>3</sup>) is estimated. This air concentration is used to calculate risk from particulate inhalation.

The Cowherd (1985) method combined with the method described by EPA (1991) is detailed, but provides an order of magnitude estimate of risk. An advantage to using Cowherd (1985) is that additional site-specific data allows further refinements to this estimate.

Uncertainties in using this model come from the following sources:

- Measured concentrations in soil (mg/kg) were used to calculate a 95 percent upper confidence limit. This 95 percent upper confidence limit was compared to the measured maximum, and the lower of the two values was used. While this is believed to be adequately conservative, an uncertainty is inherent in this method.
- Particulate emissions to air are assumed to occur at a steady rate. The wind is the force causing suspension, and particulate suspension will vary with windspeed. The Cowherd (1985) model is believed to be conservative.
- Soil concentrations are assumed to be constant. No allowance is made for decreases in soil concentrations because of biodegradation, volatilization, chemical reaction, dispersion, or for any other cause. This is conservative.
- Concentrations of contaminants in suspended particulates (mg/kg) are assumed to equal measured soil concentrations. In other words, measured soil concentrations are in units of mg/kg, and particulate contaminant concentrations are assumed to equal these measured values. Some contaminants may selectively bind to smaller, more easily suspended soil particles, making this nonconservative. However, this type of binding is not readily estimated. Hence, this assumption is used.

- The aggregate size distribution mode for the soil was estimated from photographs of the site and soil description. A silty soil was assumed, and the size range of silts was assumed as the size distribution mode. This is conservative.
- The surface silt is not assumed to form crusts, which decreases suspension in air. This is conservative.
- The correction factor applied to the threshold windspeed is conservative.
- The roughness height is conservative; loose, exposed soil is assumed.
- The degree of vegetation on site is conservatively overestimated from site photographs.
- A box model is assumed in calculating air concentrations. This is a conservative assumption.
- The diffusion height is 2 meters, which is the standard conservative assumption.

Most of the factors listed above are estimated conservatively, so that the air concentrations may be somewhat overestimated. The single exception is the capacity for a given contaminant to bind selectively to suspendable particles in soil, which is an unknown.

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CRCAT DATA 0395-13358 SEQ A

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TYPE: INFO SUPP FLWY  
SUBMITTER NAME: Allied Signal Inc.

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0002 INFO REQUESTED (TECH)  
0003 INFO REQUESTED (VOL ACTIONS)  
0004 INFO REQUESTED (REPORTING NATIONAL FI)  
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SUB DATE: 03/01/95 CRD DATE: 03/06/95 CRAD DATE: 04/03/95

107-06-2  
7439-96-5  
75-09-2  
1336-36-3

CHEMICAL NAME: Misc chemicals -> none  
~~Polynuclear aromatic hydrocarbons~~  
~~Nitrates~~  
~~None these chemicals~~  
~~None these chemicals~~

107-06-2  
7439-96-5  
75-09-2  
1336-36-3

INFORMATION TYPE	LLC	INFORMATION TYPE	LLC
0201 ONCO (HUMAN)	01 02 04	0201 HUMAN EXPOS (PROD CONTRAL)	01 02 04
0202 ONCO (ANIMAL)	01 02 04	0202 HUMAN EXPOS (ACCIDENTAL)	01 02 04
0203 CELL TRANS (IN VITRO)	01 02 04	0203 HUMAN EXPOS (MONITORING)	01 02 04
0204 MUTA (IN VITRO)	01 02 04	0204 HUMAN EXPOS (MONITORING)	01 02 04
0205 MUTA (IN VIVO)	01 02 04	0205 HUMAN EXPOS (MONITORING)	01 02 04
0206 NERVOUS/ERATO (HUMAN)	01 02 04	0206 HUMAN EXPOS (MONITORING)	01 02 04
0207 NERVOUS/ERATO (ANIMAL)	01 02 04	0207 HUMAN EXPOS (MONITORING)	01 02 04
0208 NEURO (HUMAN)	01 02 04	0208 HUMAN EXPOS (MONITORING)	01 02 04
0209 NEURO (ANIMAL)	01 02 04	0209 HUMAN EXPOS (MONITORING)	01 02 04
0210 ACUTE TOX (HUMAN)	01 02 04	0210 HUMAN EXPOS (MONITORING)	01 02 04
0211 ACUTE TOX (ANIMAL)	01 02 04	0211 HUMAN EXPOS (MONITORING)	01 02 04
0212 SUB ACUTE TOX (HUMAN)	01 02 04	0212 HUMAN EXPOS (MONITORING)	01 02 04
0213 SUB ACUTE TOX (ANIMAL)	01 02 04	0213 HUMAN EXPOS (MONITORING)	01 02 04
0214 SUB CHRONIC TOX (HUMAN)	01 02 04	0214 HUMAN EXPOS (MONITORING)	01 02 04
0215 CHRONIC TOX (ANIMAL)	01 02 04	0215 HUMAN EXPOS (MONITORING)	01 02 04

INFORMATION TYPE	LLC
0201 HUMAN EXPOS (PROD CONTRAL)	01 02 04
0202 HUMAN EXPOS (ACCIDENTAL)	01 02 04
0203 HUMAN EXPOS (MONITORING)	01 02 04
0204 HUMAN EXPOS (MONITORING)	01 02 04
0205 HUMAN EXPOS (MONITORING)	01 02 04
0206 HUMAN EXPOS (MONITORING)	01 02 04
0207 HUMAN EXPOS (MONITORING)	01 02 04
0208 HUMAN EXPOS (MONITORING)	01 02 04
0209 HUMAN EXPOS (MONITORING)	01 02 04
0210 HUMAN EXPOS (MONITORING)	01 02 04
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0212 HUMAN EXPOS (MONITORING)	01 02 04
0213 HUMAN EXPOS (MONITORING)	01 02 04
0214 HUMAN EXPOS (MONITORING)	01 02 04
0215 HUMAN EXPOS (MONITORING)	01 02 04

INFORMATION TYPE	NON-CAL INVENTORY	RECORDS REVIEW	STATUS	TOXICOLOGICAL CONCERN
CAS SR	YES	YES (CONFINEMENT)	MIN	LOW
NO	NO	NO (CONTINUED)	NO	NO

USE: PRODUCTION  
Pesticides?  
Pharmaceutical  
Infectious  
Infectious

BEST COPY AVAILABLE

### Triage of 8(e) Submissions

Date sent to triage: 2/3/96

NON-CAP

CAP

Submission number: 13359A

TSCA Inventory:

Y

N

D

Study type (circle appropriate):

Group 1 - Dick Clements (1 copy total)

ECO

AQUATO

Group 2 - Ernie Falke (1 copy total)

ATOX

SBTOX

SEN

w/NEUR

Group 3 - Elizabeth Margosches (1 copy each)

STOX

CTOX

EPI

RTOX

GTOX

STOX/ONCO

CTOX/ONCO

IMMUNO

CYTO

NEUR

Other (FATE, EXPO, MET, etc.):

Notes:

THIS IS THE ORIGINAL 8(e) SUBMISSION; PLEASE REFILE AFTER TRIAGE DATABASE ENTRY

*NO comments found.  
Please evaluate.*

#### For Contractor Use Only

entire document:

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1

2

pages

112/3

pages

8/2/95

Notes:

Contractor reviewer:

FOR

Date:

12/13/95